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Contents for June, 1947

THE ENGINEERING COLLEGE RESEARCH COUNCIL. *F. M. Dawson* 741
THE UNIVERSITY OF MINNESOTA INSTITUTE OF TECHNOLOGY 743
TECHNOLOGY AND INTERNATIONAL RELATIONS. *N. J. Padelford* 751
OPPORTUNITIES FOR ENGINEERS IN INDUSTRY. *M. M. Boring* 759
VETERANS TURNED SCHOLARS. *C. J. Freund* 762
ENROLLMENT IN MINERAL ENGINEERING SCHOOLS IN THE UNITED STATES AND CANADA AT ALL-TIME HIGH. *W. B. Plank and F. W. Bloecher* 765
WHERE ARE WE GOING? *R. E. Doherty* 771
THE FORGOTTEN MAN IN HIGHER EDUCATION. *A. A. Potter* 777
ENGLISH 113, AN EXPERIMENT IN READING. *A. M. Buchan* 780
COORDINATION IN THE TEACHING OF MATHEMATICS TO ELECTRICAL ENGINEERS. *L. V. Bewley* 786
AFTER VETERAN PROGRAMS, WHAT NEXT? *H. L. Spencer* 796
THE ENGINEER AND HIS PLACE IN RESEARCH. *A. R. Cullimore* 803
PROOF OF THE KELVIN-HELMHOLTZ EQUATION FOR THE EQUILIBRIUM VAPOR PRESSURE ABOVE A MENISCUS. *W. O. Smith* 809
THE FINE ARTS FOR ENGINEERS. *H. L. Seaver* 811
MATHEMATICS AND ELECTRICAL ENGINEERING. *G. F. Corcoran* 818
COMPARISON OF INDUSTRIAL ENGINEERING CURRICULA. *J. M. Apple* 821
PROFESSIONAL VICES OF TEACHERS OF SCIENCE AND ENGINEERING. *B. B. Bennett* 825
PHYSICS LABORATORY IN AN ENGINEERING SCHOOL. *C. J. Pratt* 828
A PRACTICAL TEACHING CREDO. *A. D. Topping* 831
PITY THE "IGNORANT" ENGINEER. *D. J. Mack* 837
WILL COMPREHENSIVE COURSES MEET THE NEEDS OF ENGINEERS? *A. L. Pugsley* 840
EDUCATE INDUSTRIAL ENGINEERS FOR ACTION. *G. B. Carson* 843
—DISCUSSION 848
GRAPHICAL AND ANALYTIC METHODS AS APPLIED TO AIRCRAFT DESIGN. *S. A. Coons* 858
A NEW METHOD OF AXOMETRIC PROJECTION. *D. Maksymiuk* 871
COLLEGE NOTES 879
INDEX 880

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55th Annual Meeting

MINNEAPOLIS, MINN., June 18–21, 1947

Host

UNIVERSITY OF MINNESOTA

The Engineering College Research Council

By F. M. DAWSON, President

In June, 1946, the Membership of the Engineering College Research Association approved in principle the merger of that organization with the American Society for Engineering Education, as the Engineering College Research Council. This action was pursuant to the formation of the A.S.E.E. with four major branches, of which the E.C.R.C. is now one. The merger was formally effected on January 1 of this year, when new By-laws for the E.C.R.C. were approved and authorized. Even before January 1, however, activities of the Research Association had been carefully coordinated with the program of the A.S.E.E.

Since the merger became effective, E.C.R.C. activities have continued to center around its three major committees. The Committee on Relations with Industrial Research Groups, authorized in June, 1946, under the able chairmanship of J. E. Hobson, Director of Armour Research Foundation, first met in December of that year. At that time its members outlined a long-range program designed to bring research facilities of the engineering colleges to the attention of private industry, and at the same time to bring the needs and desires of private industry to the attention of the engineering colleges. To this end, the Committee has arranged a symposium for the annual meeting in Minneapolis and expects to represent the E.C.R.C. at various industrial meetings during the next twelve months. The Committee has recently assisted the National Retail Lumber Dealers Association in obtaining specific information about college facilities for research in certain domestic housing problems.

Through the Committee on Relations with Federal Research Agencies, Thorndike Saville, New York University, chairman, the institutional members of the Research Council have been represented before those responsible for the extensive research programs sponsored by the Federal government, particularly the armed forces. As a result of these contacts, several observers from member institutions visited the Army Ground Forces Winter Test Task Forces in January and February; the Committee has advised member institutions of several research projects contemplated by the U. S. Army Signal Corps and Corps of Engineers, and these services have received information on which of the member institutions are interested and qualified in the fields involved.

Throughout the period of its existence, the Engineering College Research Association took an active part in the movement for a National Science Foundation; the Research Council this year has continued that interest through a Joint Committee on Federal Legislation organized with the Engineering College Administrative Council last

December. This Joint Committee was represented by Dean Saville at the hearings on the National Science Foundation legislation held before the House Committee on Interstate and Foreign Commerce in March of this year, and members of the E.C.R.C. have been kept fully informed of legislative developments. The Committee has sought to emphasize the interests of engineers in the National Science Foundation and to give impetus in any way possible to passage of legislation for a sound Foundation. Through this Committee, the Council intends to continue active support for the National Science Foundation legislation; it will interest itself in other legislation affecting the status of research and education activities in engineering colleges.

Partly to assist in the program of the Committee on Relations with Industrial Research Groups, the Research Council published this winter an "Exhibit of Patent Policies in 22 Colleges and Universities." Earlier, Proceedings of the 1946 Annual Meeting of the Engineering College Research Association were prepared and distributed. A new edition of the Directory of Member Institutions is in final stages of production as this is written. Basically revised from previous Directories published by the Research Association, the new edition will summarize briefly the research policies, facilities, and activities of all the institutional members of the Research Council. A supplementary "Exhibit of Patent Policies" is contemplated at an early date.

The activities of the Research Council have been and will continue to be aimed at expanding the usefulness of the research facilities of the engineering colleges to the nation. The Council believes that this activity will serve at least three purposes: (1) Stimulate the growth of research in engineering colleges; (2) Increase the value of research experience in engineering education; and (3) Result in engineering graduates more fully prepared to accept professional responsibilities with vision and clarity.

The University of Minnesota's Institute of Technology

Members of the American Society for Engineering Education who attend the 1947 annual meeting at the University of Minnesota June 18–21 undoubtedly will have a professional interest in the University's fine Institute of Technology.

Established by the Board of Regents November 1, 1935, the Institute of Technology embraces the College of Engineering and Architecture, the School of Chemistry and the School of Mines and Metallurgy.

Heading the Institute is its first dean, the venerable Samuel C. Lind who will retire July 1, a few days after the close of the annual meeting, following 21 years on the University staff. His successor has not yet been selected.

Dean Lind, known to his colleagues and students alike as "Lindy," joined the staff of the University in 1926 as director of the School of Chemistry and professor of chemistry. When the Institute of Technology was formed in 1935, he was the logical choice as its first dean.

Long an exponent of a broad, liberal education for students specializing in technical fields, Dean Lind was largely responsible for the recent adoption by the University of Minnesota of a five-year course for engineering students. The five-year course is not mandatory, however, for veterans.

"Should there ever come a time when all of our engineering graduates cannot obtain jobs in technical fields," the dean contends, "they at least will have had a sound general education and should be able to enter other fields quite readily."

Enrollment in the Institute has soared to an unprecedented and unexpected high this year as returning veterans, their interest in technological subjects greatly stimulated by mechanized warfare, particularly in the fields of electrical engineering, have determined to prepare themselves for careers in engineering.

Out of a total winter quarter enrollment of 5,282 in the Institute, 4,587 or 87 per cent are veterans. Enrollment in the various divisions of the Institute is as follows:

Electrical Engineering	1,437
Mechanical Engineering	1,119
Chemistry	834
Aeronautical Engineering	632
Civil Engineering	526
Architecture	298
Mining	199
Pre-business	105
Agricultural Engineering	62
Others	70
Total	5,282

Staffing the Institute to maintain the high standards of instruction for which the University of Minnesota is famous has been a major problem during the current school year. The Institute staff now consists of 325 full-time members including 231 permanent faculty members and 94 temporary appointments.

MAIN ENGINEERING BUILDING, UNIVERSITY OF MINNESOTA, ELECTRICAL ENGINEERING BUILDING AT LEFT

CENTER FOR CONTINUATION STUDY, UNIVERSITY OF MINNESOTA

Apportionment of the staff among the instructional divisions of the Institute is as follows:

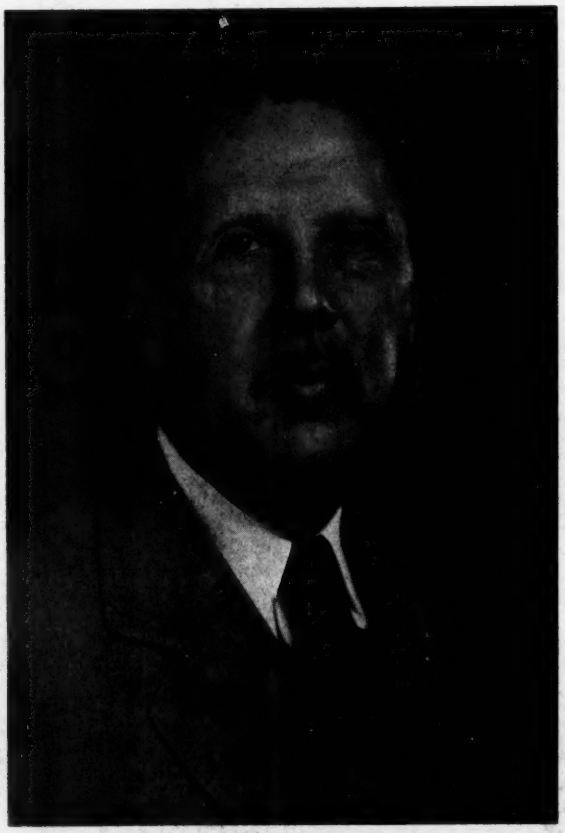
	Permanent	Temporary
Aeronautical Engineering	9	
Architecture	11	
Civil Engineering	14	3
Hydraulic Laboratory	2	2
Drawing	37	
Electrical Engineering	18	3
Experiment Station	2	4
Mathematics	52	9
Mechanical Engineering	29	5
Chemistry	35	57
Mines	13	4
Mines Experiment Station	9	7
	231	94

College of Engineering and Architecture

The College of Engineering and Architecture had its beginning in the College of Agriculture and the Mechanic Arts which was authorized by the legislative act of 1868. Courses in Civil and Mechanical Engineering were first offered in 1871. In the reorganization of the University, in 1872, the College of Mechanic Arts was established. It became the College of Engineering, Metallurgy, and the Mechanic Arts in 1892, the College of Engineering and the Mechanic Arts in 1897, and the College of Engineering and Architecture in 1916. A course in Electrical Engineering was first offered in 1887. Architecture was announced in 1912. In 1925, the name of the Department of Architecture was changed to the School of Architecture. The Agricultural Engineering course was offered in 1925, and the courses in Aeronautical Engineering in 1928. Combined courses with Business Administration were established in 1934.

The departments of this college occupy the following buildings on the Main campus: Main Engineering, Electrical Engineering, Mechanical

Mines Experiment Station, University of Minnesota
On east bank of the Mississippi River



SAMUEL C. LIND, DEAN, INSTITUTE OF TECHNOLOGY, UNIVERSITY OF MINNESOTA

Engineering, and the Experimental Engineering and Oak Street Laboratories. Portions of the School of Chemistry and the Armory are also utilized. The Hydraulic Laboratory is situated at the St. Anthony Falls of the Mississippi River about a mile upstream from the campus. Agricultural Engineering has its own building on the Agricultural campus. The libraries of Engineering and Architecture are situated in the Main Engineering Building.

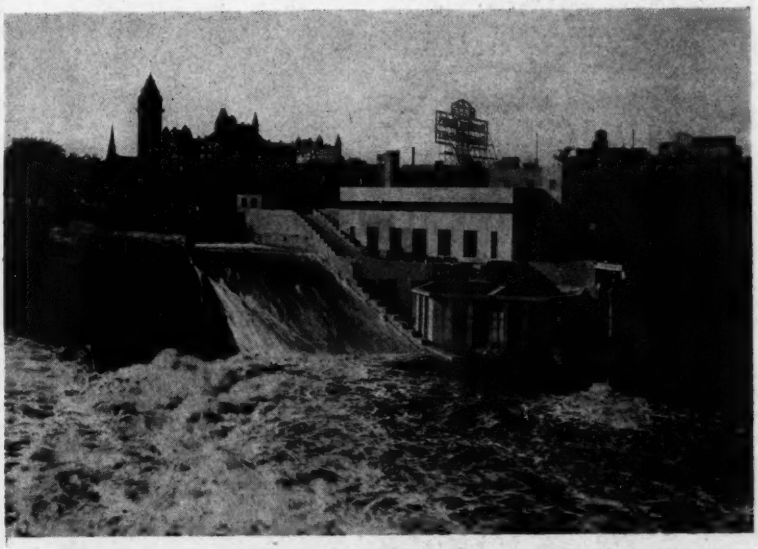
The purpose of this college is to give the students a broad foundation in the fundamental principles of engineering and architecture, together with sufficient knowledge of professional practice to enable them to apply those principles successfully.

School of Chemistry

The School of Chemistry was established in 1897 as a school of analytical and applied chemistry, subsidiary to the College of Science, Literature, and the Arts. In 1904 it was made a separate unit of the University, and in 1919, its present name was adopted, and its administration was correlated with that of the College of Engineering and Architecture under one dean.

The courses in Chemistry and Chemical Engineering were developed from the beginning of the school. The course in Physics was established in 1936.

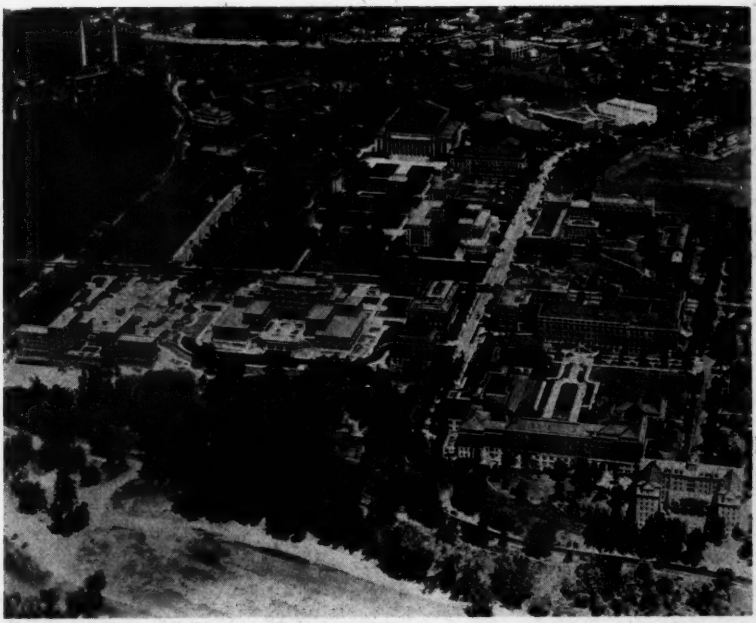
The school occupies a large modern building having six floors. Its laboratories are designed to afford facilities for instruction in the various branches of chemistry. The Chemistry library is well provided with complete sets of journals and compendia of chemical literature, among which are important sets not frequently found in university libraries. Many special laboratories for private research have been provided and ample facilities are available for graduate work leading to the higher degrees.



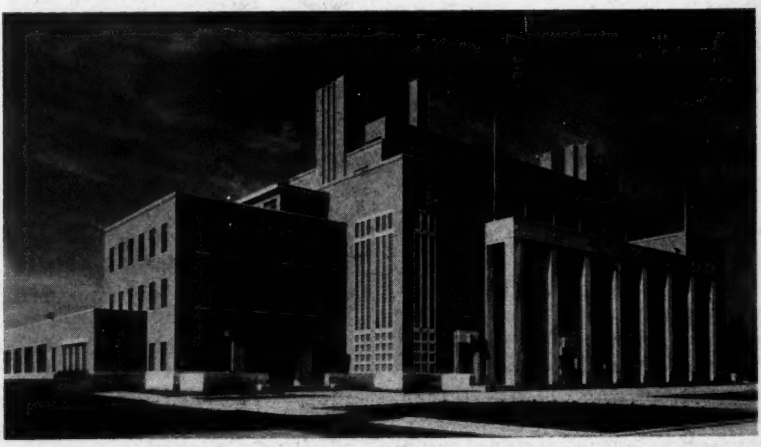
St. Anthony Falls Hydraulic Laboratory on Hennepin Island in Mississippi River, about One Mile Upstream from University of Minnesota Campus
Laboratory is at foot of historic St. Anthony Falls

School of Mines and Metallurgy

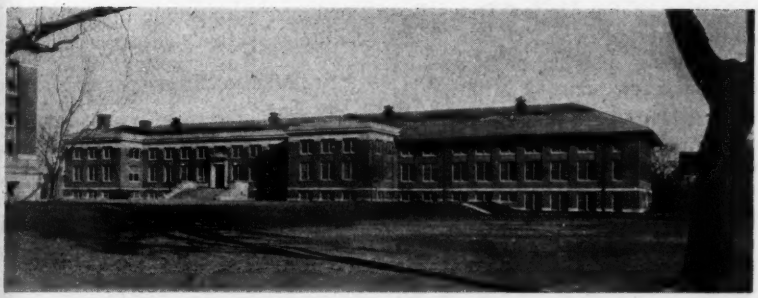
The School of Mines and Metallurgy was established by the Board of Regents in 1888, upon recommendation of the general faculty of the University. A course in Mining and Metallurgy was announced in 1889. The school was affiliated with the College of Engineering, under the name of the College of Engineering, Metallurgy, and the Mechanic Arts, until 1897,



AERIAL VIEW UNIVERSITY OF MINNESOTA CAMPUS IN MINNEAPOLIS
Engineering quadrangle at right center. Mississippi River at left. School of Chemistry —hollow square building at left center. School of Mines—just to left of School of Chemistry



COFFMAN MEMORIAL UNION, UNIVERSITY OF MINNESOTA
Named for fifth president of the University, Lotus Delta Coffman



ELECTRICAL ENGINEERING BUILDING, UNIVERSITY OF MINNESOTA
Electrical Engineering Experimental Laboratory at right

when the School of Mines was made an independent college. In 1926 the name was changed to School of Mines and Metallurgy.

The school occupies the building provided by the Legislature of 1913. This building contains the library of the school together with the offices, classrooms, drafting rooms, and laboratories necessary to administer the courses in Mining, Metallurgy, Metallography, and Petroleum Engineering. For other fields of work necessary to the completion of well-rounded curricula advantage is taken of the instruction afforded by various departments in other units of the University.

The Mines Experiment Station was established by the Board of Regents in 1911. It occupies a specially constructed laboratory building of which a portion is assigned to the North Cen-

SCHOOL OF MINES BUILDING, UNIVERSITY OF MINNESOTA

tral Station of the United States Bureau of Mines.

The mining districts of Minnesota are within a few hours of Minneapolis by rail or paved road. The heartiest co-operation exists between the officials of the various mining companies and the school. As a result, the mining properties are at all times open to parties from the school for observation and study trips. Practical surveying, geological field work, and underground work are carried on in one or more of the districts.

Ample opportunity for field work in metallurgy is also available. Numerous fabrication and heat treating plants are located in the Twin Cities. Plants for the study of smelting and other processes can be reached with not more than an overnight trip by rail.

Students in the School of Mines and Metallurgy have, therefore, all the advantages afforded by a large university combined with ample opportunity for field observation and experience.

Engineering Experiment Station

The Engineering Experiment Station of the Institute of Technology provides facilities for graduate research and technical investigations in a variety of fields. The St. Anthony Falls Hydraulic Laboratory located on Hennepin Island, one mile from the campus, and the Oak Street Laboratories are exceptionally well adapted to special large-scale investigations, many of which may be profitably conducted in co-operation with technical societies, associations, and industries. Several investigations of this type are now under way and provide an opportunity for advanced students in the institute to come in contact with industrial and technical problems. In many cases the projects provide graduate fellowships and part-time employment for advanced students.

Experimental Engineering Building, University of Minnesota

Technology and International Relations

By NORMAN J. PADELFORD

Professor of International Relations, Massachusetts Institute of Technology

When the basic pattern of American scientific education was moulded, two assumptions were generally accepted. The first of these was that the professional work of the scientist and engineer would require no knowledge of government or international affairs. The second was that the development of science would proceed upon a basis of a high degree of specialization.

These assumptions were warranted during the latter half of the nineteenth century and the early part of the twentieth century. Most engineering works were undertaken through private enterprise. Governments took little part in the development of science. The scientist and engineer had little contact with international affairs. Their work was largely related to the concerns of peace. And there were few international problems involving matters connected with technology. Likewise, it appeared clear that the specializations of science were producing both a rich, diversified economy and powerful national strength. Moreover, America, separated by the oceans from Europe and Asia, seemed safely removed from the international conflicts which periodically involved foreign nations in war.

It can now be seen that a profound change began to occur during the second and third decades of the twentieth century, destined to alter the conditions on which the original educational assumptions of the scientist were based.

American business began to draw upon the entire world for raw materials to feed its industrial machine. Large foreign markets were sought for its products. American military and naval power became a key factor in determining the balance of power among the nations not merely in the near Atlantic and Pacific, but in Europe and Asia as well. Moreover, the progression of the technological revolution, made possible by advancing science and technology, began to alter radically existing standards of living, labor conditions, communications, production, military power and a wide range of the relations between nations. What happened in Detroit or in the Ruhr affected far parts of the world, not only more quickly but much more seriously than before. A new synthetic developed in one continent became capable of throwing thousands out of employment in another. Mass produced goods could be used to flood a foreign market to drive competitors out of business. With governmental control, the radio might be used to falsify news for millions or to whip them into a frenzy for an attack upon a foreign nation. And with government direction, science and technology might be mobilized to produce weapons

capable of devastating whole cities hundreds of miles from a formal battle line.

The consequences of this change are numerous and far-reaching. American business has become inextricably tied up with world economy. Experience has demonstrated that a depression anywhere threatens prosperity everywhere. New products, revolutionary new modes of production, or changes of output in one country influence employment and production elsewhere. And because of its military and economic might, the United States has been drawn into the innermost center of world politics. No longer can it focus its attention solely upon the development of its own internal life. With Germany and Japan vanquished, with the existence for the first time in modern history of essentially a two-power world, the United States has been forced to concern itself with peace and security throughout the globe. This means the maintenance of an unprecedented power, and with it *ipso facto* an alignment of science and technology necessary to support a present-day armed conflict, until such a time as the world organization may be able to enforce peace and order.

The technological revolution has had many other consequences. One of them has been a growing need of providing international regulations for the insurance of safety, order and public protection. As a result there has been a steadily increasing number of international conferences, multilateral treaties, and international organizations relating to occupations or activities having to do with science and technology. Through these there have come to be many arrangements concerning such matters as weights and measures, air transportation, radio, hazardous occupations, public health, pharmacopoeial formulae, patents, trade marks and copyrights, navigation, laboring conditions, tin buffer stock, agriculture, fisheries, geodetic surveys and so on.

Before the advent of the technological revolution most of the works of the scientist and engineer served the arts of peaceful living. Now, in the era of total war, many of them relate directly or indirectly to a state's war potential and to its success in war. It was western technology which made a shambles of a large part of Germany, Japan and European Russia. It was technology which enabled the United Nations to coordinate their resources and their strength so that they might press the Axis Powers back from their conquests. It was the systematic application of engineering and technology which made possible a successful landing on the beaches of Normandy, winning the battle of supply across the Pacific, and inflicting defeat upon our enemies in their own home lands.

Any who have seen the devastation in Europe and in Japan, or who have stopped to estimate what another world war may involve, will agree that one of the major problems before society is how to harness technology and the power of the national states for the creation of a peaceful world before the destructive applications of science are used by warring states in such a way as to drive civilization into another dark age.

This is not the only major international problem of the day which calls for the skill of the professional world. There is an equally vital one in the question of how to raise the standard of life of millions of laboring peoples the world over so that they may enjoy more of the privileges of the well-to-do.

There are the crucial business and industrial problems of preventing violent fluctuations between periods of "prosperity" and "depression," of averting technological unemployment, of stabilizing world economy. There is the question of evolving a form of government adequately suited to handling the issues of the technological age, and the difficulty of finding some more satisfactory means of adjusting authority and liberty.

Reduced to the lowest common denominator, these great problems of the mid-twentieth century turn upon two factors: cooperation and adequate controls.

Three contemporary incidents illustrate well the indispensable factor of cooperation. The first of these can be seen in the crisis which occurred during the war when Japan seized the tin mines of Malayasia and Germany the smelters of Belgium, with the resultant necessity of the United States winning the hearty cooperation of Bolivia and engineers building suitable tin smelters in the United States. A second example may be seen in the work of scientists from at least eight lands whose efforts had to be pooled before theory could be translated into the atomic bomb. A third instance may be noted in the integration which became necessary in staff work, production, resources and scientific research on the part of the United Nations to win the war.

In each of these instances one observes the scientist, engineer and business leader being brought into intimate association with government, and through governments into acute problems of international relations. The cooperation of science and government across international lines accomplished wonders during the war. The same can be true in peace and must be practised on an even larger scale if the problems of peace are going to be solved successfully. "Cooperation is essential to the survival of a social system."

What is true of the element of cooperation is equally important in the technological age of the need of controls. And here again the engineer finds himself forced to understand details of international relations and to join hands with the statesman.

One of the important problems of the moment is the devising and enforcement of sufficiently stringent controls upon Germany so that she will not again be able to attack the peace-loving nations of the world. This involves a thorough knowledge of German industry, of the relationships between industry and war-making, as well as of the realities and limitations of international relations between the states which will have to enforce the controls. A second illustration may be seen in the establishment of an international civil aviation organization to draw up safety, public health, and navigation regulations for aircraft engaging in international air transport. A third example of the need for controls is seen in the demand for international control of atomic weapons. In this last instance the scientist is brought into immediate touch with power politics in its starkest form and also with the problems of international organization.

The difficulty which faces society is not merely that of securing more cooperation and devising more controls. There is also the human problem of the abuse of cooperation and controls. Technology has made it possible for greater news coverage to be sent from one country to another through the

radio, the telephone and the high speed cable. But science cannot ensure that thereby greater truth will prevail, that censors will not suppress information because it happens to be unfavorable, or that reports will not be colored to falsify or mislead. Technology can make transportation between nations easier and faster. But it cannot obtain entry for those whom narrow politics may decide to exclude. It cannot guarantee that those who travel will not cause trouble. It cannot make greater association mean greater accord if the minds of those who travel are warped. These are human equations, but they are amalgamated with the accomplishments of science.

As science and technology have multiplied the contacts between peoples and nations, so they have at the same time added to the possibilities of misunderstanding and conflict between nations. When nations have few contacts with one another, there are few issues over which they can dispute. Science can speed the creation of problems, it can accelerate the passage of information concerning them. There remains the irremovable fact that these problems must be settled by fallible human beings possessed of aspirations, prejudices, hesitation and obtuseness supported by the power and narrowness of the national state.

Thoughtful reflection upon the changes which have taken place within the world in the last 25 years should convince leaders of scientific education that the problems of international relations have become so immediate to the life and work of the scientist and engineer that his educational training can hardly overlook this field from now on. America is unavoidably and permanently bound into the world political and economic scene.

This is a fact which will alter the course of history. Henceforth Americans, and particularly scientists and engineers who will have so much to do with fashioning the material features of this world, must measure their knowledge against a world background. Survival and progress will depend upon knowing and acting upon the facts and the trends of international affairs.

These things being true, logic should lead to the conclusion that a study of the fundamentals of international relations should be as much a part of the education of the engineer as the study of physics and of mathematics. For the engineer functions in a human as well as in a material world. And the complexities of international affairs can no more be mastered or dealt with properly by rule-of-thumb methods than can the construction of bridges, the operation of aircraft or the production of synthetic fabrics.

The engineer called upon to advise his company regarding the wisdom of establishing a branch in a foreign country, or to interpret the international consequences of a government subsidization of some new industry, needs a body of knowledge which the traditional education in the sciences does not provide him.

If it be objected that the average engineer would have no use for such knowledge and hence should not sacrifice valuable time from professional subjects, two observations remain to be made. In the first place, a careful inquiry into the activities of engineering graduates will reveal a surprising percentage engaging in work related in one way or another to international affairs. An examination of the records of the alumni of the Massachusetts Institute of Technology revealed that before the Second World War one out of twelve

of all graduates—excluding foreign students—went to work abroad. Further study of these records showed that within thirty years of graduation 70 per cent of the graduates occupied executive positions in business in many instances of which the firm was engaged in foreign business. Comparable figures could no doubt be found in other institutions as well.

No successful business man, no naval officer or statesman, can deal with foreign affairs without knowledge of facts and forces any more than he can deal with problems of production or logistics without them. Hence, if education aims to supply the graduate in engineering with the tools wherewith he can deal intelligently with the kind of problems he may well encounter, international relations is a subject which should be included in his mental tool kit.

There is a second consideration which applies to the education of the engineer whether he goes abroad or not, or whether he goes into a business engaging in foreign commerce or not. This is that as a citizen in a democracy he should be able to form reasoned judgments on national issues and be able to exercise the duties of citizenship intelligently. As an educated man, society has a right to look to him for responsibility in the assumption of public office if called upon to do so. With the complexities involved in the formation and execution of foreign policy today, it is obvious that without some study these obligations cannot be discharged with the skill which the public is accustomed to expecting of the trained engineer. The scientific institution, therefore, has itself a certain responsibility to the community to graduate men and women who will strengthen rather than impair the life of the state.

International relations used to be handled exclusively by diplomats appointed from the ranks of politicians or from college graduates schooled in the liberal arts. It has become clear that this type of statesman is not competent to handle many of the technical international problems which arise today. Symptomatic of the changing times are the facts that within recent years one of the Under Secretaries of State of the United States, who is in charge of economic questions, has been appointed from the ranks of big business leadership, that appeals are being made for engineering graduates to enter the United States Foreign Service, that groups of scientists and engineers are frequently being called into consultation in the Department of State or by the President to help form policy on technical matters or to join American delegations to international conferences, and that such professional men are being asked to accompany the Secretary of State and President to the most critical international gatherings. This is a tendency which may be expected to grow in the future. Similar requests for service may be anticipated from the United Nations organization as its Military Staff Committee, the Atomic Energy Commission, the Economic and Social Council and other technical agencies get under way.

Impressed with these considerations, the Massachusetts Institute of Technology in 1944 decided that International Relations should be made one of four Humanities subjects from which every senior should choose a year course.

Much thought was given to the objectives which a course in International Relations for engineering students should seek to accomplish. A review of the typical courses given in the liberal arts colleges was convincing that on the

whole these were not adapted to the needs of the scientific school. It was found that frequently they were devoted to diplomatic history, the technicalities of international law, or to the framework of international organization.

It has been felt that a course in International Relations for the engineer should do more than introduce him to the minutiae of some technical subdivision of the field. It should aim to give him an acquaintance with the field as a whole, emphasizing those aspects which are dynamic in the world of today. It should develop in particular those factors, forces, problems and methodologies which have a bearing upon the role of the scientist. It should help him understand the news of the day. It should provide him with sufficient knowledge so that he can distinguish between fact and propaganda; so that he can handle international problems when he is faced with them. Moreover, such a course should fit him to occupy his station as a responsible citizen, and to adjust himself with reasonable efficiency to the duties of public office having to do with some features of international relations if he is called upon to do so or urged by conscience to seek such positions of leadership.

Stated somewhat differently, it is believed that a course in International Relations for engineering students should not be less than two semesters in length and should aim at the following goals:

(1) The development of an understanding of the basic factors and techniques of politics and of international relations;

(2) The cultivation of a grasp of the policies and positions of the major states;

(3) Knowledge of the United Nations' organization and its operation, as being the instrumentality which will do much to direct international cooperation in the coming years;

(4) The acquisition of ability to analyze current international issues, to estimtae their relative significance, and to think out intelligent ways of dealing with them;

(5) Attainment of an understanding of the techniques of sampling, interpreting, and influencing public opinion on matters relating to foreign policy and international affairs;

(6) Careful study of the connection between the developments in technology and international relations; and finally,

(7) Cultivation of a sense of personal responsibility for the promotion of sound national policies and more peaceful international relations.

It is the conviction of the Institute that any narrower set of objectives would fall short of satisfying the requirements of the present technological age. A less comprehensive course would be too superficial to meet the highest professional standards. Or it would tend to become too specialized for inclusion in the limited curriculum of the engineering school.

The content of a course in International Relations, like the objectives, should be based upon a consideration of the needs and later activities of the engineer.

Special thought needs also to be given to the teaching methods employed in such a course. The old-type large lecture course is hardly suited to the accomplishment of the objectives in mind. There must be ample opportunity for discussion, for a thorough exploration of problems.

In his work the professional man must make constant estimates of current situations confronting his undertaking. He must be able to reason intelligently from given facts to definite decisions of action. These attributes apply with equal force to the professional man's contact with international affairs. Consequently, the study of International Relations should be carried on in such a way as to develop these abilities in this field.

To accomplish these purposes the student should be faced with a succession of case problems. He should be required to deal with them as if he were in a position of responsibility in industry, government, foreign trade or the armed services. Only in this way can he be given that measure of experience which will mature him for the tasks he will meet in life.

In conclusion, it should be observed that the teaching of international relations along the lines indicated above requires instructors possessed of exceptional training. The teacher must have had a broader graduate training than has normally been the case with college instructors in this field. He must have a thorough grasp of economics, politics, geography, social change. He must be familiar also with technological change.

Above all, the teacher must have his "feet upon the ground" in contemporary international relations. He must be a master of what is taking place in the world. He should be a practically minded man, disposed to adapt the scientific method to the teaching and study of this subject. Finally, he should have had personal experience with the relations of nations either in government, business or foreign service.

Only in these ways can instruction be insured which will raise the study of international relations to the level of the sciences.

In a speech prepared for delivery on an occasion which unhappily followed his death, President Franklin D. Roosevelt observed that "if civilization is to survive we must cultivate the science of human relationships—the ability of all peoples of all kinds to live and to work together in the same world at peace." This expresses well the philosophy which must underlie the knitting together of the work of the engineer and the political scientist.

Francis Bacon believed that science, if given a suitable opportunity, could enlarge "the bounds of human empire, to the effecting of all things possible." This is no doubt true in the physical sense. Yet mankind is beginning to comprehend that the full realization of this can be attained only if the scientist and engineer on the one hand, and the political scientist on the other hand join forces. For as Charles Merriam has observed, "mind is master," and regardless of the discoveries of science or the developments of power through technology, the mind of man through the instrumentalities of the state can both control, curb, direct and stimulate the activities of science.

If there is to be a more peaceful world there must be a mastery both of the realm of scientific achievement and of the restlessness of man. To do this there must be a better application of the scientific method to human relations, and at the same time a humanizing of science.

The accomplishments of man in civilizing entire continents, in bridging the oceans, in harnessing the energy of the atom, and in obtaining agreement among 50 nations on an organization for peace and security give room for hope that if the scientist and

the student of government can concert their endeavors a better world and a more abundant life can be attained in the years that lie ahead.

It has been said that, "The highest goal of science is the welfare of human beings." It has long been taken for granted that the goal of government is the ordering of human affairs to the end that there may be an advancement of the well being of society. With the powers both of construction and of destruction which are now at the fingertips of science, the time has come when the student of engineering must become as versed in the handling of human relations as he is of the tools and materials of the physical world.

Opportunities for Engineers in Industry*

By MAYNARD M. BORING

General Electric Co., Schenectady, N. Y.

The industrial opportunities for the technical graduate are probably brighter than they have ever been or will ever be again.

First, let us analyze the industrial situation from the technical manpower needs. During the roaring '20's we had a great boom in technical education, and industry clamored at the doors of the colleges for more and more men. The great development of the motor car, the expansion of the communication industry, the new field of radio and the demand for consumer goods for the home provided an incentive that attracted large numbers to the colleges, and all found jobs in the industrial field. Public utilities absorbed many graduates. The oil industries went through a great expansion. Demands for fuel for the auto, the airplane and fuel for automatic heating demanded greatly expanded facilities and manpower so that the colleges were hard pressed to keep up with the need.

Unfortunately, much technical manpower was wasted and it became a fact that technical men were used in many places where people with other training or no formal college training could have performed almost as well.

Then came the day of reckoning when jobs were scarce and a very small number of technical graduates could find places in their field. Many had to seek employment outside their calling and have been permanently lost to the technical field. As you well know, several classes were so affected and the many engineers from the classes 1932 through 1938, with the possible exception of the class of 1937, were lost as far as engineering is concerned. The colleges rightly kept on producing good men but their placement and usefulness were indeed inefficient.

Full production came and lasted but a short time before the war and the pent-up demand for goods, after the 1932 fiasco, was little relieved in that short full-production period, as even then the demand for war goods was staggering. Then war production demands were upon us and it became impossible to fill our still active demand for peace time goods.

Following World War I we were able quickly to overcome the lack of technical manpower because the great era of technical development had hardly begun and during that troublesome period the production of technical manpower was not impaired to any extent. Courses were almost standard and the training was broad and fundamental.

During World War II vast changes were made in our education and the colleges went all out to help win the war so that the number of graduates dwindled almost to the vanishing point, and industry was able to obtain only a very small and frankly, poor quality of engineering graduate. The speed-up

* Presented at the meeting of the Upper New York Section, A.S.E.E., November 2, 1946.

plan was not good education as any user of technical people, I am sure, will agree. That kind of education is but a thin veneer poured over the immature boy, and much of it, I am afraid, ran off without making any real lasting impression.

It is a fact that jobs change rapidly. It is my observation that changes happen in the experiences of all people as long as they are progressing so that jobs become different jobs about every five to ten years. In other words, the ladder of success for all of us has a slope determined by our abilities and other characteristics, but the rungs of these ladders are spaced about equally in time. If this is true, each space between the rungs may be considered to be a generation. Each generation then will in their time replace older groups and eventually they will be replaced by younger groups. This cycle goes on and on, and each generation is necessary to carry on our technical tradition.

Industry finds itself then in a most peculiar situation. First, we lost a large percentage of our generation produced in the '30's, and we have not produced a generation in the early '40's. True, many of those had their education interrupted by the war and are now returning to college. Many will eventually graduate out of phase but with unusual maturity. We must find a way of providing experience rapidly in order that this group may find a way of bridging the gap so rudely caused by the war.

The continued impingement of Selective Service on us is largely preventing the high school graduate from entering the engineering colleges. This means a further delay and loss of technical manpower for several years to come.

To further complicate the problem the great depression and the war stopped the production of the skilled mechanic. The engineer may continue his developments but the lack of draftsmen to lay out designs and toolmakers to make models tends to delay production and to keep new developments from the factories. We have always depended not only on our apprentice programs to produce these vital skills but also in the past have had a flow of such people from abroad. This flow has stopped as other countries have also stopped apprentice training during the war years.

The war period has created a tremendous advance in science and in materials. New alloys with undreamed of qualities have been developed. These must be put to use. We have learned by experience how to produce under war pressure new products that have immeasurable usefulness in our normal life.

These young men must help solve the great labor problem and educate the factory worker to the fact that only by production can we create wealth. He must become cost conscious, learn to conserve our raw material and manpower. We must have better quality and better methods of production and distribution.

The industrial picture has a serious technical manpower shortage in the group that are now 32 to 40 years of age, the ages which supply the most productive technical people. The younger groups which should back them up have been greatly diminished also. These two groups are expected to get the industrial machine into high gear and to do this job with the most serious lack of skilled and semi-skilled labor in history.

The development of the airplane and consequent shortening of distances, high speed trains and other transportation means require improved and continu-

ally improved equipment, methods and other technical services.

The chemical industries are on the threshold of their greatest productivity. New materials, metals and synthetics, already developed or well on the way to completion, demand technical help never dreamed of before. Additional power is in demand and with the probable use of atomic energy the utility or general power field will undergo a tremendous upheaval and technical changes. The use of electronics has just begun, not only in communications but in control of everything under the sun. Gas turbines are with us not only for use in airplanes but are equally useful on ships, locomotives and other means of transportation.

Many of these new, radical and now well-known things have been developed by industrial research which has reached a high plane and will continue to develop new products. Under our economy industrial research organizations, forced ahead by the competitive spirit, will continue the progression we have enjoyed in the past.

Communication in a peace time world has necessarily lagged as have all phases of our normal peace time activities. Our friends in telephone and telegraph are finding it necessary to expand and develop to keep up with the increasingly complex communication systems.

One of the more critical problems of today is our material shortage, particularly in the fields of metals and metal products. We all have read about shortages of copper, steel and lead. One of the basic reasons for this is that the returning G. I. does not want to mine metals and coal. This means that further technical development of mining and metal processing equipment as well as safer and better working conditions must be developed in order to again attract young men to these industries.

One could continue indefinitely in such an analysis of all industries and services. We can see for ourselves the conditions with which we are faced. We must depend on the young technical graduate to carry on in spite of these difficulties in the industrial world and expect him to not only provide the peace time goods and services but also to continue to develop better weapons for defense and to keep ahead of other countries to provide in America the standard of safe living which we all demand.

Under these conditions industry cannot again afford to use technically trained men on anything but jobs requiring their full abilities. New industries demand technical manpower be taught this important fact, and the colleges must produce to the limit the quality of men needed to do this tremendous task. There can be no place for any but the strong in this race.

The unbalanced age distribution alone among our technical people will force these younger men to spread themselves over a wide band of responsibilities, and they will be required to take over older men's jobs at a rate never before equaled. We need the maturity of the returning service men and we must teach these boys that they have responsibilities just as deep as those that they had during their war service. They won the war and they must keep America and the whole world going ahead. Those in industry are just as responsible for our future welfare as any other group.

These facts can then be called the opportunities for the technical graduate in industry. There can be no ceiling for the young graduate who possesses those traits and abilities that make for success, and his opportunities today are greater than ever before.

Veterans Turned Scholars*

By C. J. FREUND

Dean, College of Engineering, University of Detroit

"What we want to know is what you men in the University are going to do for the veterans." That is what the Committee on Economic Education of the Detroit Board of Commerce asked Ralph Johnson, University of Detroit Industrial Coordinator, and myself on October 2, 1944. Of course, they were much more diplomatic and courteous about it, but that is what they meant. By this time, the Board is entitled to some kind of report, some sort of answer to the committee's question.

Most of the students in the University are veterans. Fifty-two hundred of them registered for the autumn semester. They are 68 per cent of the total enrollment of 7,616.

The veterans are not dawdling; 80 per cent of them are carrying a full load of studies, according to Professor Paul Harbrecht, Director of the University's Veterans' Bureau.

Seventeen per cent of them are married. Nearly all are Detroit boys, sons of Detroit parents, and as they mostly live in their own homes, the housing problem in the University is not as critical as in many other colleges and Universities.

In the College of Engineering of the University, there are 1,469 veteran day students, who constitute 78 per cent of the total day enrollment of 1,861. The proportion of veterans among the 342 evening students of engineering is doubtless about the same. Ninety-five per cent of day engineers are full time students.

The heavy enrollment of veterans has severely taxed resources and facilities, as the following tabulation of total engineering registration will suggest:

Spring, 1945	256
Autumn, 1945	429
Spring, 1946	1,093
Autumn, 1946	2,203

Obviously, it has been no easy task to assemble a competent and adequate faculty; and to procure and install sufficient laboratory equipment and machinery, build and rebuild classrooms and laboratories as needed, and obtain books and supplies—all in competition with hundreds of American colleges and univesities.

The following discussion of familiar problems pertains to the College of Engineering; I am not qualified to speak for the University as a whole. I cite some of the statements made that are disproved.

"The colleges will be so harrassed by the swarm of veterans that standards of instruction will certainly collapse."

Many new members have joined the Engineering faculty but they have been as carefully selected as ever before; there has been no letting down of the bars.

* Reprinted from *The Detroiter*, February 17, 1947.

Work in the classes and laboratories is as effective as before the war. Of course, sessions are held at inconvenient times—on Saturdays, early in the morning, evenings, during the noon hour—but no actual damage has been done. Convocations, assemblies, extra curricular activities have been sacrificed to the emergency here and there, but twenty-five veterans in Room 311, on Monday, Wednesday and Friday mornings, are learning just as much about sanitation and water supply as their older brothers of ten years ago.

"The veterans won't stick it out. There will be few of them left in the colleges in a year or two. Fighters can't be cooped up in a classroom."

This prophecy has been false, at least so far. 1.5 per cent of the engineering veterans withdrew from September 9 to January 6 of this year. This compares with 7.2 per cent withdrawals during the same period last year, out of the entire engineering student body, of which 76 per cent were non-veterans at that time.

"The returning veteran will be badly out of adjustment and hard to handle. The colleges will need to establish psychiatric clinics on a large scale."

We expected anything and everything. We argued that a boy who has spent two or three years being shot at ought to be at least nervous. Besides, we got ready for some irritating, if harmless strutting: "Who won the war? We won the war!"

Well, the veterans streamed into the University, literally by the thousands. And they were no different from any other young Americans, except that they turned out to be a little more mature, a little better behaved, a little more serious, a little more successful in their studies, and distinctly more conscious of the purposes of college work.

There are no psychiatric clinics in the University. None are needed. The counselling of veterans has to do with courses and vocational matters, not with the correction of psycopathic disorders.

"You college professors will have to get on to yourselves when the veterans return. They won't put up with all your hocus-pocus of credits and degrees, and four years of monkeying around. They will demand streamlined education."

So we spent six precious and painstaking months laying out a new, two year program for the veteran who wants quick and concentrated training for a good job in the Detroit industries, without the finishing touches and the ornaments of a full professional education.

Not one veteran signed up for the course. A thousand signed up for the old fashioned curricula in engineering.

In spring of last year we assembled the veterans in the College of Engineering and asked them: "Do you men want some sort of refresher course, something to get you back into the groove?" They answered "No," with emphasis.

"Then what do you want?" "We want to go on where we left off." "You mean in the regular old programs leading to engineering degrees?" "That's what we mean."

One man had some misgivings about it, but the rest hooted him down. And they made it abundantly clear that they were not interested in any "Learn the Japanese language in thirteen efficient weeks" sort of thing. They were tired of being hurried and pushed.

"Sure, give the boys an engineering education if they want one; they're entitled to it. But whoever will hire all those thousands when they come out of college? Where are you going to put them to work?"

Dr. Karl Compton, Massachusetts Institute of Technology, was chairman of a committee of the American Society for Engineering Education which surveyed American industries and engineering colleges last year in order to compare the demand from the industries for graduates, and the anticipated supply from the colleges.

At the annual meeting of the Society at St. Louis last June, he reported a deficit of 35,270 engineers in the industries in 1947, after absorbing about 13,000 expected graduates. The deficit will grow to 37,000 by 1949, and the supply of graduates will not overtake the demand until 1952. By that time all, or practically all, of the veterans will be out of the colleges. It looks as if the temporary bulge of veteran students will just about cancel out the temporary shortage of engineers.

This is a brief answer to the question: What are we doing for the veterans in the University of Detroit?

The veterans keep us busy. We have less time than we should like to see friends downtown and to take even a small part in civic undertakings. Indeed, we have a major civic job right here in the College of Engineering.

But it is a fascinating job; it is easy to do all we possibly can for those fine lads. If it hadn't been for them, we should be starving to death in some unspeakable prison camp—or dead.

Enrollment in Mineral Engineering Schools of United States and Canada at All-Time High*

By WILLIAM B. PLANK† AND F. WILLIAM BLOECHER, JR.‡

The current enrollment of 12,892 students in the mineral engineering schools of the United States and Canada marks an all-time high record for these schools. It shows a remarkably rapid recovery from the effects of World War II. The enrollment in all the other engineering branches has also increased but not as rapidly as in the mineral engineering branch.

The data in this report are from the eighth questionnaire study of the mineral engineering schools made, as formerly, under the auspices of the Mineral Industry Education Division of the A.I.M.E. The study was carried out in the same manner as in former years. Also, as in former years, 100 per cent of the schools are represented in the data, for which the authors thank the deans and professors who supplied the information. For these reasons, therefore, the data of all the studies are comparable, an achievement not always possible in endeavors of this kind. For comparison with the general engineering enrollment situation, data are included from the January, 1947, issue of the JOURNAL OF ENGINEERING EDUCATION.

The term *Mineral Engineering,* as it has been used in these reports for several years, is a generic term that embraces all the specialized activities carried out by engineers who have to do with the mineral industries. To train engineers for these activities, separate engineering curricula are offered by the United States and Canadian schools that are included in this report. These curricula are: Mining, metallurgy, petroleum and natural gas, ceramics, geology, and fuels. An admirable discussion of the suitability of this term, by A. B. Parsons, Secretary of the A.I.M.E., appears in the January, 1947, issue of *Mining and Metallurgy.*

Shortly after the close of the academic year, 1938–39, two months before the beginning of the World War II conflagration, the mineral engineering schools of the United State and Canada, with their 10,633 students, were enjoying their highest enrollment up to that time. During the war years, when mineral engineering students were not considered essential, the enrollment plummeted to an all-time low, estimated at 1,262, in the year 1944–45. At this time the total engineering student population in both countries was 41,632. At the close of the war in 1945 the veterans and civilians began to return to the engineering schools in large numbers, until in the current year, 1946–47, 12,892 mineral

* A Paper presented at the Annual Meeting, A.I.M.E., New York, March 16, 1947.

† Head of Department of Mining and Metallurgical Engineering, Lafayette College, Member.

‡ Instructor in Mining, Lafayette College, Junior Member.

TABLE I

MINERAL ENGINEERING STUDENT ENROLLMENT BY COURSES
1946–47, UNITED STATES, 57 SCHOOLS

Course	Fresh.	Soph.	Jr.	Sr.	Total Under-graduates	Grad. Studs.	Grand Total	Cand. B.S. Degree
Mining	989	479	320	230	2,018	70	2,088	223
Metallurgy	948	750	570	421	2,689	470	3,159	403
Pet. and N. Gas	1,559	1,058	663	461	3,741	187	3,928	424
Ceramics	332	246	165	120	863	138	1,001	94
Geology	450	302	203	112	1,067	127	1,194	97
Fuels	3	8	15	7	33	16	49	5
Specials							3	
Totals	4,281	2,843	1,936	1,351	10,411	1,008	11,422	1,246

TABLE II

MINERAL ENGINEERING STUDENT ENROLLMENT BY COURSES
1946–47, CANADA, 8 SCHOOLS

Course	Fresh.	Soph.	Jr.	Sr.	Total Under-graduates	Grad. Studs.	Grand Total	Cand. B.S. Degree
Mining	359	208	118	67	752	5	757	53
Metallurgy	141	86	50	35	312	11	323	35
Ceramics	10	13	7	4	34	—	34	4
Geology	142	93	49	21	305	51	356	19
Totals	652	400	224	127	1,403	67	1,470	111

engineering students are enrolled in both countries out of a total of 222,557 engineering students in all branches. The data in Table IV are used in making these comparisons.

The enrollment of 12,892 students in the mineral engineering schools of both countries represents an increase of 320 per cent over last year. In the same period the entire engineering enrollment increased from 73,269 to 222,557, or 204 per cent. The current enrollment of 11,422 in the United States mineral engineering schools is 20 per cent above the previous high of 9,619 in 1938–39. In Canada, during the same period, the enrollment increased from 1,014 to 1,470, or 45 per cent.

The romance of mineral engineering has for a number of years attracted a few women into the field. This year, however, this appeal has been responded to by the greatest number of women ever recorded. Forty-nine women are enrolled in the United States schools and one in a Canadian school, with the larger percentage in the schools west of the Mississippi River. All together there are 1,375 women engineering students in the United States and 48 in Canada.

As was to have been expected, mineral engineering as a life career has also made a strong appeal to veterans. They comprise 78 per cent of the students in the United States schools and

70 per cent in the Canadian schools. In all the engineering branches in the United States, veterans make up 50 per cent of the total enrollment, and in Canada 28 per cent.

Of the 11,422 mineral engineering students in the United States, the petroleum group, with 34.5 per cent of the total, has regained the first place which it held before the war. The metallurgists hold second place, with 28 per cent of the total; and the mining engineers are third in rank, with 18 per cent.

Graduate students in the United States schools, as shown in Table V, have increased in number to the highest recorded total: 1,008 men and women. This is 143 per cent larger than in 1938–39. In Canada the 67 graduate students represent an increase of 80 per cent over the same period.

While the mineral engineering schools have been receiving this influx of students the same thing has been happening in the other engineering branches, and indications point to increasing enrollments for several years. The figures in Table IV, Column (5), show that the other major engineering branches are also at their peaks. They rank as follows: mechanical, 44,403; electrical, 38,963; civil, 30,079; and chemical, 23,600.

The continuance of governmental aid for veterans and the expected discontinuance of Selective Service, plus the present unfilled demand for engineers of all kinds, are bound to keep engineering enrollments high for a number of years. This applies espe-

TABLE III

ENGINEERING ENROLLMENT BY CLASSES, UNITED STATES, 1946–47, 130 SCHOOLS

From JOUR. OF ENGR. EDCN., Jan. 1947

Courses	Fresh.	Soph.	Jr.	Sr.	5th Yr. and Others	Total Undergrads.	Grad. Studs.	Total
Mining	762	695	424	278	8	2,167	135	2,302
Metallurgy	741	655	488	396	137	2,417	762	3,179
Pet. and N. Gas	1,136	947	573	379	13	3,048	?	3,048
Ceramics	274	234	153	93	42	796	144	940
Total Mineral Engineers	2,913	2,531	1,638	1,146	200	8,428	1,041	9,469
Chemical	5,631	6,014	4,374	2,987	1,439	20,445	3,155	23,600
Civil	10,910	8,338	4,961	2,793	1,446	28,448	1,631	30,079
Mechanical	13,787	12,049	7,669	5,960	2,707	42,172	2,231	44,403
Electrical	13,984	10,420	5,901	3,650	2,174	36,129	2,834	38,963
Others	33,478	11,054	6,082	3,904	7,657	62,175	3,241	65,416
Unclassified						1,059		1,059
Total Engrs.:								
United States	80,703	50,406	30,625	20,440	15,623	198,856	14,133	212,989
Canada	3,949	3,311	1,384	836	88	9,568	*	9,568
U. S. + Canada	84,652	53,717	32,009	21,276	15,711	208,424	14,133	222,557

* Included above.

cially to the mineral fields where the unfilled demand for engineers has not been met since the war began and will likely not be met for a long time. If we assume that the freshman mineral engineers now enrolled are filling the freshman halls of the schools to capacity, and if this capacity continues to be filled in ensuing years, then it is estimated that eventually there will result an enrollment in both countries of about 16,000 mineral engineering students. This estimate is arrived at by using the percentages of survivals to graduation from among entering freshmen, as shown in the JOURNAL OF ENGINEERING EDUCATION, September, 1946, Page 37. These percentages are: for freshmen, 53.8 per cent; for sophomores, 64.7 per cent; and for juniors, 71.8 per cent.

With this large student body in our mineral engineering schools, one of the serious problems, among others, that is facing the institutions is how to staff the faculties with properly qualified teachers. All administrators know how serious this problem is at this time. As proof of the seriousness of the situation, this year's study reveals that

TABLE IV

ENGINEERING STUDENT ENROLLMENT BY COURSES, UNDERGRADUATES AND GRADUATES, 1936–37 TO 1946–47

Courses	(1) 1936–37	(1) 1938–39	(2) 1941–42	(3) 1944–45	(4) 1945–46	(5) 1946–47	(6) 1946–47
Mining	1,652	1,892	1,501	224	553	2,302	2,088
Metallurgy	1,630	2,403	2,712	472	1,214	3,179	3,159
Pet. and N. Gas	2,466	3,538	2,143	376	1,083	3,048	3,928
Ceramics	738	825	746	190	249	940	1,001
Geology	567	844	?	?	?	?	1,194
Fuels	66	24	?	?	?	?	49
Spec. Studs.	71	93	?	?	?	?	3
Total Min. Engrs.:							
United States	7,190	9,619	—	—	—	—	11,422
Canada	881	1,014	—	—	—	—	1,470
U. S. + Canada	8,071	10,633	7,102	1,262	3,079	9,469*	12,892
Chemical			17,778	5,082	7,766	23,600	
Civil			11,374	3,537	7,233	30,079	
Mechanical			28,564	6,965	13,553	44,403	
Electrical			15,348	5,934	12,082	38,963	
Others			35,062	18,852	29,556	66,475	
Totals			115,228	41,632	73,269	222,557**	

(1) *Mining and Metallurgy*, May 1946.
(2) JOURNAL OF ENGINEERING EDUCATION, December 1941, U. S. and Canada.
(3) JOURNAL OF ENGINEERING EDUCATION, December 1944, U. S. and Canada.
(4) JOURNAL OF ENGINEERING EDUCATION, January 1946, U. S. and Canada.
(5) JOURNAL OF ENGINEERING EDUCATION, January 1947, U. S. and Canada.
(6) Study of "Mineral Industry Education Division, A.I.M.E.," November 15, 1946.
* Total U. S. Students plus Canadian Graduate Students.
** Includes 9,568 Canadian Undergraduate Students, Unclassified.

TABLE V

DISTRIBUTION OF MINERAL ENGINEERING GRADUATE STUDENTS, UNITED STATES, 1933–34 TO 1946–47

Courses	1933–34	1934–35	1936–37	1938–39	1940–41	1942–43	1946–47
Mining	40	55	49	44	44	20	70
Metallurgy	116	93	131	172	215	137	470
Pet. and N. Gas	18	29	58	43	75	27	187
Ceramics	19	36	48	64	50	19	138
Geology	46	62	34	86	127	9	127
Fuels	4	10	18	6	9	10	16
Totals	243	285	338	415	520	222	1,008

only 34 of the United States seniors and graduate students expect to enter teaching, and only 96 of the seniors expect to enter graduate schools. In Canada none were reported as intending to teach as a career, and only seven expect to enter graduate schools. This problem lies principally at the door of the professors who, through counsel and guidance, should turn the attention of qualified students to the teaching profession. The graduate schools should be the reservoirs from which more teachers should be drawn.

Of the 25 comments on the teacher situation, made on a total of 66 questionnaires, 13 indicated that low salaries were the greatest hindrance in securing adequately trained instructors. The comments ranged from, "I wish I knew," to the surprising observation, "A depression is also favorable, encouraging men to select a stable income." The use of qualified graduate students as instructors is practiced at a number of institutions. Several stated that teaching loads which will permit progress towards advanced degrees will attract some good men.

It is apparent that the nearest available source of instructors and assistants is the graduate student group. The practice of using the time of graduate students to do teaching is not ordinarily commendable. But a condition approaching a crisis will soon exist in the teaching staffs of our schools, and perhaps many institutions will be compelled to revert to the practice. There are compensations for this system, however, because it affords teaching experience to prospective candidates for the profession.

Industry, as well as the engineering school faculties, must draw its trained engineers largely from the new graduates. The trend in this supply by the United States and Canadian engineering schools is as follows:

FIRST DEGREES CONFERRED, ALL ENGINEERS

1942–43	14,714
1943–44	11,155
1944–45	4,724
1945–46	8,219

The number of mineral engineers to receive their first degrees in June, 1947, as shown in Table I, is 1,246 in the United States, and 111 in Canada. If we deduct from these figures, 96, representing those who expect to enter graduate schools in the United States, and 7 in Canada, we have remaining 1,150 mineral engineering graduates in the United States and 104 in Canada, or a total of 1,254, to fill the cur-

rent and cumulative demands of the mineral industry and the mineral engineering schools.

The educators in the mineral fields and all the employers of the products of the mineral engineering schools should continue their interest and participation in guidance activities to insure that only qualified people are selected to enter the mineral engineering profession. The special need for this guidance has long been well known. And in the years ahead, with ever increasing complexities in mineral discovery, production, beneficiation, processing and utilization, this need will become more and more pressing.

It is a pleasure to report that the National Roster of Scientific and Specialized Personnel, which has already produced four guidance pamphlets concerning the various branches of mineral engineering, is planning to issue soon another pamphlet defining the professions of mining, metallurgical and petroleum engineering. During the past year the A.I.M.E., through the Seely W. Mudd Memorial Fund, has issued the third edition of "Careers in the Mineral Industries." This pamphlet by T. T. Read, first issued in 1939, has met with favor among young men. From the Australasian Institute of Mining and Metallurgy has recently come a new pamphlet entitled, "Mining and Metallurgy as a Career." All of this literature should be made readily available to young men who are choosing their life careers.

To the directory of mineral engineering schools, that has always accompanied these periodic surveys, have been added three schools in the United States and one in Canada. The University of Pennsylvania and Drexel Institute have begun new curricula in metallurgical engineering. The Illinois Institute of Technology will begin to register students in September, 1947, for a newly organized undergraduate course in metallurgy. A new curriculum in mineral dressing is contemplated at a school in the East. Montreal University appears on the list this year for the first time.

Many of the schools have overhauled, reorganized and enlarged their curricular offerings in the light of present-day requirements of engineering education for the mineral industries. Four schools have lengthened their courses from four years to five or six years. Three schools are offering degree courses in geophysics for the first time. One school has dropped its course in ceramic engineering and another has discontinued its course in ceramics.

"Where Are We Going?" *

By ROBERT E. DOHERTY

President, Carnegie Institute of Technology

Let me ask you to call up in your minds the picture of social and economic conditions in our country and in the world. Then while you are looking at this picture, let me ask you a question: where do you think that we as a people are going? Where do you, individually, come into this picture? You are in the boat; you have to go wherever it goes. But it is part your boat, and you can have a say in setting the course. What do you hope to do about it? How can you prepare to do it?

Let us consider the first question—where are we going? Somebody must answer this question, because inevitably we shall go somewhere, even if we drift. I for one don't know, and I don't know anybody who can tell me. I don't even know where we, as a people, really want to go, because we as a people haven't made up our minds. But we think we know. We cite the Constitution and the Bill of Rights and the Four Freedoms and free enterprise and the rights of Labor, and so on; and then we say, "These represent what we want." Now I believe that the great majority of American people do want these things. But they want a lot of other things too—things that are inconsistent with these. We are confused—terribly confused—about the difference between what we want and what it takes to get it. How many millions of people have accepted and try to live by the false doctrine that they can get something for nothing—and still be polite about it!; that they can get the fruits of somebody else's work without doing equivalent work; or that the fruits of a great national economy can be sacrificed for the temporary benefit of their own group; or that they can keep freedom for themselves and yet deny it to others? No, we not only don't know where we are going; we don't even know where we are. Like Columbus in one version of his voyage: when he went, he didn't know where he was going; when he got there he didn't know where he was; and when he returned, he didn't know where he had been!

We must become clear on where we want to go—clear on purpose. I wish to rivet down in your minds an old but very important idea—namely, that lack of purpose leads to chaos. Or stated the other way around, clear and definite purpose, if recognized in practice, leads to accomplishment. And this, let me remind you, is just as true for bad purpose as for good purpose. Each of you, I am sure, knows persons who have floundered in their lives, lived in chaos, because they couldn't make up their minds about anything. But there are several degrees of floundering. I dare say that each one of you is now struggling with purpose. Many of you, of course, have settled on a choice of career, but important as that

* Presented at Carnegie Day, November 26, 1946.

is, it represents only a small segment of life purpose. And your struggle with other questions gives you at least a feel of the chaos that goes with lack of purpose. It becomes actual chaos only if you finally give up and become accustomed to living in confusion.

On the other hand, you have undoubtedly known of persons among your acquaintances and in biographies who represent the opposite, who achieved a rounded-out philosophy of life and thus also achieved, if not great wealth, then great satisfactions that make life worth while.

For further illustration turn to organizations. Whether it is a group, a community, a nation, or the world, the idea holds. Consider a group—the labor union, for example. Here you find in most cases definite purpose that is recognized in practice by the group. What else do you find? I will tell you: you find effective accomplishment. Or, take the business organization. Here also if you find clear and definite purpose that is recognized in practice you usually find also effective accomplishment. If individual purpose and national purpose and world purpose were as clear and as fully accepted in practice, so would be their accomplishments. The point I am making here is that lack of purpose leads to chaos, and conversely that a purpose which is clear and accepted leads to accomplishment.

But obviously this idea needs further qualification. Mind you, I said of such labor unions and such business organizations that their accomplishments were "effective"; I did not say they were always wholly good; indeed they may be very bad in both cases. Not only must there be purpose that is clear and accepted in practice; it must be good purpose, and it must also be related to other purposes. For instance, the purpose of the labor union to obtain proper wages and working conditions for its members certainly is a good purpose. What is bad in many cases is that this purpose evidently omits recognition of any higher purpose; from the point of view of one type of labor leader, now unfortunately often in the saddle, the purpose is evidently the *primary* purpose, it transcends all others; and being primary, it demands that the union led by such a leader do every thing in its power to accomplish it, regardless of the rights of others, regardless of a higher purpose of the community or nation. Some examples are the recent power strike in Pittsburgh, the maritime strike, the present coal strike.

Thus, in addition to the requirement that the purpose be clear and accepted in practice, is the requirement that there be an intelligent relationship between the purposes of individuals, of communities, of States, and of the nation. In other words, there must be not only purpose but a hierarchy of purpose—a structure that makes sense as a whole in which at successive levels the purposes are reasonably adjusted to those above, all being thus related to the great overall national aims which we as a people profess and which, as they are stated in the Constitution, represent the highest moral purposes.

Now this, I must confess, is an idealistic concept, but it is also a realistic one—one which thinking people must see and continue to hold in mind. Because if they do, then perhaps they can figure out where we are going, or want to go; and when enough individuals know that, there will be reason for hope that groups, communities, and the nation which these individuals partly constitute will also know. I therefore want you to see and hold this concept in mind as we examine further into this problem

of where we are going as a nation and what you can do about it.

I have said that we need purpose, good purpose, a hierarchy of purpose. We do have now a statement of national purpose—the Constitution—but we need something besides its very general sailing directions. Because all that we now pay attention to in practice is the direction in which the ship must go when it is about to sink, and the imperative duties of the crew under that condition. These particular directions under such circumstances are clear, definite, and recognized. We had a chance to feel the weight of them during the late war. However, before and after the impending disaster, the ship's course is forgotten and the duties become directed to the day's business on board in which each group seeks the greatest advantage for itself.

What we need, therefore, alongside the Bill of Rights is a Bill of Responsibilities. Wherever there is a right, there is a commensurate responsibility; and hence there must be also a hierarchy of responsibility to correspond with the hierarchy of purpose. This old truth is threadbare but still important. But we hear little emphasis upon our responsibilities—especially responsibilities to the great national aims under which we profess to live and to the welfare of the community in which we make our homes. The responsibilities we hear most about these days are the responsibilities of the labor leader to his union, the congressman to his constituents or to the bloc that supported him, the company to its stockholders, the pressure group to its members, the individual to his family and employer. Let me hasten to say that these are not bad responsibilities; they are legitimate and they are necessary. But they are not primary; they do not come first. We have demonstrated in four great wars that when our life as a free people is manifestly threatened with disaster, all of these other responsibilities are actually secondary. The incredible fact is, however, that just as soon as the immediate danger is removed, we forget the primary responsibility. It seems that the danger must be not only present; it must be in the form of a clearly impending disaster. Otherwise we shut our eyes and let the insidious, but real, dangers creep up on us. Indeed we insist on it. We set in motion forces of internal disruption, and without the restraint and direction which this primary responsibility would provide if it were recognized, we assume the dog-eat-dog attitude and let secondary responsibilities completely rule our lives.

The Civil War is a good illustration, for this habit I am discussing is not new with the American people. By 1861 internal forces had grown until the condition I have mentioned was fulfilled—the condition that is necessary for the recognition of primary responsibility: disaster was clearly impending. Then there was a shift in responsibilities; then our homes, our business, even life itself became secondary. When the war was over, what happened? Did we continue to face that primary responsibility which Lincoln to the end certainly did continue to see and to urge upon us? Did we follow his purpose to rebuild the nation strong by nursing the wounds of war and helping the South, as well as the North, to restore itself? No, we let bitterness of group against group hold sway and thus created cleavages that still persist after these 80 years.

And we are doing the same thing today. World War II having now ended, we find that bitterness and strife and internal chaos characterize the national

scene. Deep cleavages are developing —have developed—and I don't believe we can stand them now as we have in the past. The rapid pace today and the magnitude and character of the forces involved will, I fear, bring chaos if we continue to drift without clear over-all purpose and clear responsibility. But we are still running true to form.

What I have been saying is that if we hope to endure as a free people, we must as a people learn how to put first things first, how to keep our dominant, primary purpose *always* clear, how to recognize our responsibilities as well as our rights, and in this way learn how to adjust the policies and procedures of our daily lives and business to accord with that purpose. This means rational discrimination among values and purposes and responsibilities—doing which, let me remind you, is an intellectual act—and it also means thinking out accordingly what to do—and this too is an intellectual act. In no other way can we know where we are going nor how to get there; in no other way that I see may we avoid chaos.

Where do you come into this picture? What can you do about it? Perhaps what I just said may have given you a clue—namely, that intellectual effort on a high plane is absolutely necessary. So I can tell you that your role must be a significant one, and earnestly urge you to understand and remember this. Let us now consider what that role must be.

When I asked the question, "Where are we going?" I said that somebody *had* to answer it. But who? If we lived under a totalitarian regime, the answer would be simple, but the way we are set up to run the country there is no single person or pressure group that can answer the question—although if I may be facetious about a serious matter, there have been those who have tried to. Our democracy rests upon the assumption that the people themselves are competent to make the great policy decisions that determine the course of our national life. And, may God bless them, they have demonstrated more than once that they will do so if they understand. Sometimes they take decisive action when they don't fully understand but know only that something is wrong.

But the trouble is too frequently that they don't understand all that they should. Their understanding is of surface conditions, not of basic issues; it is, for instance, understanding of personal frustrations and hardships caused by strikes and too much governmen meddling, not understanding of the fundamental responsibilities that were being violated. Moreover, at the speed of change today, by the time surface conditions become so intolerable that they drive people to the polls it can well be too late to make a correction.

So one does not have to look far to find a fundamental difficulty that now stands in the way of the successful operation of our plan of democracy. It is that great policy questions are extremely complex, and the intellectual and moral requirements for dealing with them are therefore very austere. To define the issues clearly and precisely, to weigh them against our great national purpose in the first instance—the purpose for which, if need be, we will fight—and in the second instance, against all other considerations; and then to devise means for helping the people to understand these issues, and practical plans for solving the problem —doing these things requires extraordinary intellectual capacity and discipline—such indeed as may not be expected on the part of all citizens, but certainly may be expected from some.

If there is an answer to this difficulty,

as I believe there is, the hope for its realization lies in men and women who have had the special privilege of cultivating their intellectual powers in college and who thus also have responsibility for using them: responsibility for helping to formulate policies and procedures; responsibility for supporting good measures and interpreting them to their fellow citizens; and responsibility for taking an active hand in civic and community affairs. If we had this intellectual power and moral conviction at the sources of policy formulation—that is, in congressional and other legislative committees and in all positions of group leadership—and if we had also a sprinkling of informed and thinking citizens among the populace who were actively interested in the responsibilities I have mentioned, then we should have, I believe, a solution to the present basic weakness of our democracy. Then perhaps the electorate could be expected to understand better earlier and therefore to vote more intelligently. Then perhaps also we could give a more definite answer to the question, "Where are we going?"

But this whole concept is predicated upon the assumption that such intellectual and moral leadershp as I have mentioned will be available. It thus assumes that the colleges will cultivate such people. You are such people, and that is the answer to the question, "Where do you come into the picture?"

But you have to do more than merely enter the picture; you have to prepare for it. But how? Where can you find the time? Is such preparation worth the time and effort that could otherwise be put on your technical studies? There is a good answer to this question, and I shall try to give it to you.

It is probably not the answer you would give. You wish to become professional men and women as quickly as possible, and this, you probably believe, should mean spending practically all of your time on technical studies. Many of you look down your educational road in a straight, narrow line and see at the far end only one spot—the technical spot—in what is actually a large professional area, and thus tend to place serious and unnecessary limitations on the development of your powers.

Let me ask you, What are techniques and technical knowledge for? They are media of expression and interpretation. They are very important—indeed essential—but they do not constitute the whole of professional competence, unless indeed one considers a professional man to be no more than a technical craftsman. I said that they are media of expression and interpretation, but of what? Of something a mind somewhere has conceived.

The source of creative professional power is the cultivated mind. It is not one that is merely full of technical information and of knowledge of technical routines; it is one that has enough of these PLUS creative vision, analytical power, humane understanding, a perspective of social and economic evolution, and the power to continue to learn and to develop in all of these respects. Such a mind has the capacity for creating, for solving problems—whether in art, engineering, science, or other fields represented at C.I.T.—and thus the capacity also for arriving itself at something worth expressing or interpreting.

Let me call your attention to the fact that these requisites that I have suggested are only partly in terms of knowledge; they are primarily *qualities* of mind—qualities that must be achieved, won by continued devotion and effort. They cannot be learned

out of a book alone nor by one's being told about them.

Then there are two other things to be said about them. First, they are just as important for professional accomplishment as for competence as a citizen. This is true, I contend, for all professions, but it is especially true for engineers, for their work at genuine professional level cannot be separated from the human, social, and economic factors. And secondly, these qualities cannot be cultivated in technical studies alone. The beautiful thing about them is that, being qualities of mind and not mere knowledge of subject matter, they are a common denominator of all fields and are developed the stronger as they are cultivated in more fields.

I have already suggested that their cultivation is not easy. It is a long, hard pull, but so worth while!

It means, in the first instance, the establishment of purpose, and this is not done by a New Year's resolution. It must be built step by step, by trial and error, by weighing values against experience and new understanding, by fitting purposes together so that they make sense as a whole. I have mentioned a hierarchy of purpose, and it is as essential for the individual as for communities—perhaps more so, for building it is of course building a philosophy of life.

As you build it, certainly one early element will be your educational purpose which will become broadened to encompass these qualities of mind I have mentioned. And a second early element, I hope, will be a growing sense of responsibility to use your increasing intellectual powers in the interests of your community and country as well as of your personal careers. And that is my idea of how you can prepare to enter the picture that I have presented this morning.

I want you to become such professional men and women and such competent citizens, who will match privilege with responsibility and thus make the highest possible contribution to your profession and to your country; and thus will also enjoy the satisfactions of a full and creative life. And if you try as hard to become such professional men and women as your institution is trying to help you do so, you will succeed.

The Forgotten Man in Higher Education*

By A. A. POTTER

Dean of Engineering, Purdue University

Dr. Oliver C. Carmichael, President of the Carnegie Foundation for The Advancement of Teaching, in the forty-first Annual Report of that Foundation, states that "One sometimes gets the impression that the teacher, the central figure in the educational process, is a forgotten man; and that effective teaching, the essential factor, is taken for granted." Unfortunately, this is not an impression, but a reality. Educational buildings, dormitories, alumni, equipment, research, extension, curricula, athletics—all of these matters which involve educational planning, public relations, activities and facilities, are constantly in the forefront before the administration and governing boards of educational institutions of higher learning. Too little attention seems to be given to the improvement of the quality of teaching: too few realize that the teacher may enlighten and strengthen; or he may poison and weaken the mind of the learner. In the words of Henry Adams, "A teacher affects eternity"; his influence may be very great and lasting, for good or for bad. Well worked out curricula, superior educational plants and equipment, effective educational administration and excellent public relations are useless without good teachers. A college or university is largely the reflex of its teachers.

Having devoted forty-one years to teaching; and to the discovery, selection, training, and encouragement of teachers, the following observations may prove of value to those interested in effective teaching:

Teaching is not only a science, but also an art, perhaps largely an art; and like any art, it is individual. Every teacher has his own art. With some it is mastery of the subject taught; with others it is a gift for clarity of expression or the power of persuasion. Some teachers have a talent for bringing every subject from the abstractions of a textbook to the experience lived. Still other teachers have the ability to initiate inquiry and to set their students at tasks of observation and comparison. Woodrow Wilson's success as a teacher was traced to his ability to develop in his students the feeling of the beauty and power of words: he had a passion for the verbal communication of his ideas. Some people are able to communicate extraordinary things through the use of ordinary words.

Unbounded and contagious enthusiasm is definitely an important asset for a teacher. Louis Agassiz, of Harvard University, is said to have had an "intense and comprehensive enthusiam for his subject." The master teacher radiates his enthusiasm about him in the sparkle of his eye and the vibrance of his voice. He fascinates his students by his general animation, by his engaging

* Presented at the Illinois-Indiana Section A.S.E.E. at Rose Polytechnic Institute May 10, 1947.

manners, by his vigor, by his dress, by his dignity, and by his interest in the subject he teaches.

Humanity is another distinguishing feature of the great teacher. This he shows by his keen interest in the individual student, by his kindness and courtesy, by his candor and fairness, by his tolerance and understanding, by his cheerfulness and simplicity, and by his optimism and unlimited patience. He understands and loves his students as he understands and loves the subject he teaches. His personality is attractive. It was Goethe who said: "We learn only from those we love."

The master teacher knows his students, penetrates beneath the surface, and brings out the best in them; always recognizing possibilities as well as actualities. He adjusts his teaching to the preparation and aptitude of the individual student. He is always cheerful and shuns the pitfalls of pessimism. He is always ready to encourage and to help. He looks beyond his day, into his pupil's day. Hopefulness and a large expectancy of the future are effective assets in dealing with young people.

The great musician and teacher of music, César Franck, is said to have given to each of his pupils direction and instruction best suited to his temperament. He excelled in his power to penetrate his pupil's thoughts and to take possession of them, while scrupulously respecting his individual interests and aptitudes.

The effective teacher has infinite patience, an unlimited capacity for taking pains, and perfect self-control. He never uses sarcasm, threats, or profanity to attain his objective.

He lives up to high ethical standards. He does not condone dishonesty, deceit, trickery, or the evasion of the laws of the land on the part of his students or colleagues. He is sincere, does not bluff or exaggerate; is absolutely moral, dependable, punctual, clean, just, industrious, mentally honest and courageous; and has the ability to inspire and instill in his students sound character, worthy ambitions, and an appreciation of right living.

He is not a hireling or a time saver; but is deeply interested in his calling. He loves his work and devotes himself loyally, cooperatively, and unselfishly to his students, his colleagues, and to his profession.

The great teacher has a lively and irrepressible intellectual curiosity and freedom from personal preoccupation. He has the ability to analyze and synthesize the facts involved in any problem; and to arrive at solutions objectively, and without prejudice. He has cultivated good habits of study; and knows how to organize and how to impart knowledge. He realizes, however, that the objective of education is not to drill knowledge into people, but to strengthen their mental capacities; and that good teaching does not result in individuals crammed with mere facts, opinions, or phrases of other people; but people who have ability to think and to form their own opinions. He encourages his students to use their own minds, and to avoid following furrows traced for them by others.

The effective teacher has a thorough mastery of his mother tongue and expresses himself clearly, correctly, and logically. He talks audibly enough to be easily heard; and his enunciation is such as to be readily understood. He is constantly enlarging his vocabulary by reading well-written books and magazines; and encourages his students to do likewise. His general education, his professional attainments, and his culture command the respect, not only of his students, but also of his academic colleagues and the public.

He is a master of the subject he teaches; and is constantly improving his knowledge by advanced study and reading, practice, travel, research, and contact with leaders in the same field.

He aids his students to discover their aptitudes and to derive maximum benefit

from their studies by learning how to study, how to plan their work, and how to make best use of their time. He develops the students' proper attitude toward their studies and surroundings, aids them to differentiate between facts and opinions, and impresses upon them the necessity of developing an analytical attitude and an appreciation of human values.

Research in an academic institution has as its major objective the improvement of its principal product—the student. Mere experimentation does not take the place of scholarly endeavor; neither does competence in research, alone, take the place of inspirational teaching, which stimulates people to clearer thinking, greater endeavor, good citizenship, and human decency. Research, either in the specialty of the teacher or in teaching methods, is essential to keep the teacher up to date. All good teachers are scholars. They are constantly trying to excel in their field through the writing of books, papers, and articles; research; professional practice, and through lectures and addresses, which are the result of study and research. Teachers who are not interested in improving themselves through research, study, travel, professional contacts, writing, or speaking; who do not contribute to their own specialty through active participation in scientific and learned bodies; and who are unknown even in their own field, have little inspirational value and are usually found to lack initiative, intellect, or ability to improve others. The master teacher shuns intellectual ruts, as he realizes that a rut differs from a grave only in dimensions and outlets.

The college or university teacher, as a member of a great profession, always has a sense of responsibility for the welfare and effectiveness of the members of his profession, and is particularly intesested in the growth of his younger colleagues, as well as in his students. He guides and instructs the young teacher, even though he may see in him a rising rival for prestige and preference. He realizes that all people in an academic institution are learners; teachers and pupils alike are scholars. He opposes gaps between student and teacher, and between teachers of different ranks. He realizes that all people in academic institutions are colleagues who must cooperate in the interest of the learner and for the advancement of knowledge. The higher the academic rank he occupies, the greater is his responsibility for the guidance of others. If he is called upon to assume administrative responsibilities, he has an additional responsibility to interpret the needs of his staff to his academic superiors, and to become the guardian of the standards and prestige of the university, college, school, or department entrusted to his care. The higher the academic administrative position one holds, the greater is his responsibility to act as a catalyst who stimulates, inspires, and encourages his colleagues in their scholarly endeavors.

Finally, it must be remembered that the compensation of the teacher is not represented by the salary he receives or by the academic rank he holds: much of his satisfaction comes from work well done in an atmosphere which is conducive to high ethical standards, human sensitiveness, and productive scholarship. He loves his work and derives satisfaction from the successes of his colleagues and students. The teacher is certainly fortunate in the rewards and satisfactions of life which his calling affords him!

English 113, an Experiment in Reading

By ALEXANDER M. BUCHAN

Professor of English, Washington University

Across the faculty lunch table we were discussing the familiar topic of the place and importance of "culture" in the training of scientists. One of our colleagues, a physicist, made his own position very clear:

"We want our promising students young and we want them to ourselves. They have no time for literature or economics or philosophy, and they need language only to help them read science. If we are going to survive in the war of the sciences, we must have a race of brilliant young men trained in science from their early college years and fit for research in their early twenties. Those are the men we have to rely on, and those are the men we must educate."

"But what will they know," asked a teacher of literature timidly, "of the world around them? How can they use their science for the good of society if they have never been taught anything about man or society?"

"They can read, can't they?" said the physicist in tones of scorn. "We get most of our knowledge of society from reading anyhow."

"They can read." A few of them do read, and these are the ones in our scientific groups who are most afraid of the kind of training proposed by the physicist. Unfortunately, however, the majority do not read, not in the sense in which the teacher of literature spoke. They keep abreast of technical magazines, they glance at the daily newspaper, they master technical reports and write many of them, but the literature that speaks about man and society, man's aims and society's inadequate efforts to achieve them, they have neither time nor taste for. And why should they? Books that are too contemptible to be included in their college curriculum are certainly beneath the dignity of a practical man of affairs.

It was in the belief that engineering students who are not taught to read in college will probably not care to read afterwards that Dean Langsdorf suggested the course English 113. Like other deans of engineering, he has been appalled at the ignorance that college students display of the most ordinary facts and ideas of the society in which they live. He has practically come to accept grammar as a lost cause and free, fluent expression as a remote ideal, but he refuses to condone in grown men and women an almost total illiteracy of interest and idea. Literature, economics, social theory, even the arts and the philosophies, ought to have some slight influence on the minds and attitudes of "practical" men.

To make this influence noticeable, however, is a great deal harder in the shaping of a curriculum than it appears to be in theory. The majority of engineering students consider literature sissy stuff, taught by and worthy

of women, and usually so taught as to induce a kind of intellectual nausea. There is no clear proof that the liberal arts courses in literature which have been designed by scholarly experts and are handled in the interests of future Ph.D.'s in the humanities, have any appeal beyond that of grade for the average student; and courses in great books and the history of ideas are still experimental. Until the four-year engineering curriculum has been generally extended by one or two years, anything like a full measure of "cultural" reading is frankly impossible.

Any substitute will make one concession to our physicist who pins his faith in reading: it will not try to cover the field but it will try to awaken an interest in reading and keep it alive. It will skirt the dilemma of the "masterpieces" course which tries too much and falls down of its own pretentiousness. It will concede that the engineering student has a limited time for general reading and that much of this time should be given to reading rather than to classroom procedure. And it will be fitted to the assumption that, barring the accident of dull teaching, an important work of literature or philosophy or social theory does kindle the interest of young men and women of college caliber.

On these premises English 113 was devised. There is no classroom schedule, the work being carried on by conference. Each section contains about 18 students assigned to four conference groups and the instructor sees each group once every two weeks. The student's responsibility is to read one book in the two-weekly period, to report on it to his instructor, and to answer intelligently any question he may be asked about it. During a semester, therefore, he reads an average of six books and hears reports and discussions on from eighteen to twenty-four additional books.

Obviously, the selection of reading material is extremely important. For the original course seven categories were drawn up: fiction, science, biography and history, philosophy and religion, government and economics, drama and poetry, and the arts. A rather arbitrary selection was made of what were confessedly favorite volumes of the teaching staff and the list of these selections was given to the students along with permission to depart from it if the instructor agreed. Since it was out of the question to expect any one instructor to know all of the books on the list, he was free to recommend his own favorites to the groups and, if he cared to narrow the scope of the conference work, he might have the four or five students of a group concentrate on one important book.

No attempt was made to confine the list of reading to so-called masterpieces. The obstacle in the way of teaching really great literary works is the need for a far greater amount of explanation by the teacher than this conference schedule allowed; so that, while Plato's "Republic" was on the list, a student, if he preferred, could read Walter Lippmann's "U. S. Foreign Policy." The important matter, it seemed, was not so much to give the young engineer a digest of the best thinking about government, whatever that may be, but to have him read and discuss a tolerably good book on some phase of government so as to accustom him to thinking and speaking along political lines.

Just as masterpiece standards were ignored, so too were those of the professional teacher of English. Since the

instructors were all members of the English staff, their choice of favorites would certainly not satisfy teachers of history or philosophy or science, but they leaned over backwards to do justice to the preferences of non-literary readers. Preferring Thackeray or Hawthorne, for instance, they also wrote Lloyd Douglas and Steinbeck into their list; and they made a place for Newton and Hogben although they felt that the "Principles" and "Mathematics for the Million" are remarkably dull books.

Any estimate of results is, of course, premature and already a number of modifications seem called for.

1. Some of the desirable books are costly and substitutes must be found until cheap editions are available. With a more plentiful supply of paper and a book trade realizing the profits to be made from cheap editions, this difficulty will soon be overcome. At least one publishing house has already begun to issue 35 cent editions of classical works that seem to be in demand for courses of this sort.

2. The schedule of two hours' conference a week is inadequate and was arranged simply because classes and labs made it impossible to bring teachers and students together more often. Some teachers have met the difficulty by giving additional conference time to individual students, and it may be feasible to schedule meetings of all sections in which to discuss the broad issues suggested by the main categories of reading.

3. Grading the students is difficult. While there is a noticeable difference between the clear, pointed reports of the very good students and the slovenly comments of the unthinking ones, it is hard to distinguish between B's and C's unless arbitrarily. One of these arbitrary methods is to insist on written notes of reading and to judge these by the familiar standards of English composition.

In spite of these handicaps, the results which are beginning to appear are happy. Without exception the students do their reading on schedule, make their reports with a marked show of interest, and express pleasure at the opportunity to make comments as they see fit. They are given time to read books which they would never otherwise have bothered to read and they are surprised to find themselves liking it. Since many of them are veterans, they have probably a clearer sense of the urgency of social issues than the ordinary undergraduate would have, and the desire to work out some sort of personal philosophy makes them appreciate the hints supplied by literature, religion, and the arts. In this respect, it is delightful to find a generation of young men refusing to rise to the bait of the once-popular doctrines of Alexis Carrel and being rather bored with the decayed intellectual gentility of Henry Adams.

More pleasing than the general response is the willingness of many of the students to read more than they have to. One quite mediocre lad found himself lured by a recent book of reminiscences about F. D. R. into a rather comprehensive survey of American foreign policy from the annexation of the Panama Canal area to our present imbroglio with Russia, and even if his final grade was C he is a considerably better citizen for having taken the course. Such basic ideas as those of Darwin, Marx and Freud were, for the most part, too complex for any of the students to grasp except in a very elementary fashion—as, indeed, they are for most readers—but the attitude of approaching the

"Origin of Species," for example, as a book to be read and not as a text for a prescribed course in genetics encouraged freer reporting and franker comment than is usual among young engineers.

No apology was ever made to the students for the large number of recent books on the suggested list, and the contemporary flavor did much for the popularity of the course. In our English department there are few if any instructors who subscribe to the St. John's-Chicago throw-back to primitive origins in thought, and, without any disrespect for Lucretius or Seneca or St. Augustine, they guessed that Irwin Edman or John Dewey might prove as potent a stimulus of philosophic mood in pragmatic youngsters as these older writers. The results seem to justify the guess, if one's aim is to produce thoughtful engineers rather than engineering philosophers.

Perhaps the real virtue of such a program lies in its lack of pretension. Young people are invited to read not so much because it's good for them as that they will show a lively interest in the books they read. Under the whiplash of a thoroughly organized course in masterpieces, these students would probably display the customary reluctance to be instructed. Asked simply to read and discuss, they seem quite eager to do a measurable amount of thinking and to enjoy doing it.

ENGLISH 113*

Category I, Fiction: *Anderson,* Winesburg, Ohio; *Caldwell,* God's Little Acre; *Cather,* My Antonia, Death Comes to the Archbishop; *Conrad,* Lord Jim; *Dos Passos,* U. S. A.; *Dostoevski,* Crime and Punishment; *L. Douglas,* The Robe, The Magnificent Obsession; *N. Douglas,* South Wind; *Dreiser,* Sister Carrie, The American Tragedy; *Farrell,* Studs Lonigan; *Faulkner,* As I Lay Dying; *Hardy,* Tess of the D'Urbervilles, Jude the Obscure; *Hemingway,* Farewell to Arms, For Whom the Bell Tolls, The Sun also Rises; *Hersey,* A Bell for Adano; *Hudson,* Green Mansions; *Huxley,* Brave New World, Antic Hay, Point Counterpoint; *Jackson,* The Lost Weekend; *Lewis,* Arrowsmith, Babbitt, Main Street; *Mann,* Buddenbrooks; *Maugham,* Of Human Bondage, The Razor's Edge, Moon and Sixpence, Cakes and Ale; *McCullers,* The Heart is a Lonely Hunter; *Morley,* The Haunted Bookshop; *Steinbeck,* Of Mice and Men, Grapes of Wrath, Tortilla Flat; *Wilder,* The Bridge of San Luis Rey, Heaven's My Destination.

Category II, Science: *Boyle,* Skeptical Chemist; *Carrel,* Man the Unknown; *Darwin,* Origin of Species, Descent of Man; *Dampier-Wetham,* History of Science and its Relations to Philosophy and Religion; *Eddington,* Nature of the Physical World; *Euclid,* Elements; *Faraday,* Experimental Research in Electricity; *Galton,* Inquiries into the Human Faculty; *Harvey,* Motion of the Heart and Blood; *Hogben,* Science for the Citizen, Mathematics for the Millions; *Jeans,* The Universe Around Us; *Kellogg,* Human Life as the Biologist Sees It; *Mendel,* Papers; *Rickard,* Man and Metals; *Russell,* Icarus: or the Future of Science; *Thomson,* Modern Science; *Thornton,* Science and Social Change; *Van Loon,* Geography.

Category III, Biography and History: *Adams,* The Education of Henry Adams; *Bryce,* American Commonwealth; *Cellini,* Autobiography; *Chamberlain,* Soviet Russia: A Living Record and a History; *De Kruif,* Microbe Hunters; *Franklin,* Autobiography; *Hayes,* Historical Evolution of Modern Nationalism; *Lenard,* Great Men of Science; *Livy,* History of Rome; *Ludwig,* Napoleon; *Merezhkovski,*

* This original list was compiled by Mr. Wm. Inge and Mr. R. Schlich of the department of English.

Romance of Leonardo Da Vinci; *Pupin,* Immigrant to Inventor; *Renan,* Life of Jesus; *Sheean,* Personal History; *Stefansson,* Northward Course of Empire; *Strachey,* Eminent Victorians; *Symons,* Life of Michaelangelo; *Thucydides,* History of the Peloponnesian Wars; *Wells,* Autobiography, Outline of History.

Category IV, Philosophy, Psychology, Religion: *Adams,* Everyman's Psychology; *Adler,* Understanding Human Nature, Science of Living; *Marcus Aurelius,* Meditations; *Aristotle,* Nichomachean Ethics; *Bergson,* Creative Evolution; *Browne,* This Believing World; *Cabot,* Meaning of Right and Wrong; *Carlill,* Socrates and the Emancipation of Mankind; *Dewey,* Psychology and Social Practice, Philosophy and Civilization; *Durant,* Mansions of Philosophy; *Edman,* Human Traits and their Social Significance, A Philosopher's Holiday; *Freud,* A General Introduction to Psychoanalysis; *Hocking,* Types of Philosophy; *James, Wm.,* The Principles of Psychology; *Jastrow,* Effective Thinking; *Lippmann,* Preface to Morals; *Lucretius,* Of the Nature of Things; *Machiavelli,* The Prince; *Overstreet,* About Ourselves; *Pascal,* Pensees; *Robinson,* Man as Psychology Sees Him, The Mind in the Making; *Rochefoucauld,* Maxims; *Russell,* The Analysis of Mind, The Outline of Philosophy; *St. Augustine,* Confessions; *Sargent,* Basic Teachings of Two Great Psychologists; *Sheldon,* Psychology of the Promethean Will; *Thomas à Kempis,* Imitation of Christ; *Thorndike,* Human Nature and the Social Order.

Category V, Sociology, Government, Business, Economics: *Arnold,* The Symbols of Government; *Chase,* Economy of Abundance; *Cole,* Guide Through World Chaos; *Davies,* Mission to Moscow; *Davis,* The Young Man in Business; *C. Day,* This Simian World; *Flanders,* Traming our Machines; *Hobbes,* Leviathan; *Jacks,* Constructive Citizenship; *Kimball,* Principles of Industrial Organization; *Laski,* Reflections on the Revolution of Our Times; *Lippmann,* U. S. Foreign Policy; *Marx,* Kapital; *Mumford,* Technics and Civilization; *Plato,* Republic; *Rousseau,* The Social Contract; *Smith,* The Wealth of Nations; *Siegfried,* America Comes of Age; *Streit,* Union Now; *Tead,* Art of Leadership; *Thoreau,* Walden; *Van Loon,* Story of Mankind; *Veblen,* Theory of the Leisure Class; *Wells,* The Outline of Man's Work and Wealth; *Willkie,* One World.

Category VI, Drama and Poetry: *Aristophanes,* The Frogs, Lysistrata; *Baudelaire,* The Flowers of Evil; *Benet,* John Brown's Body; *Chekov,* The Cherry Orchard, The Three Sisters, Uncle Vanya; *Dante,* The Divine Comedy; *Donne,* Poems, Sermons; *Dowson,* Collected Poems; *T. S. Eliot,* Murder in the Cathedral, Collected Poems; *Euripides,* Alcestis, Medea, The Trojan Women; *Housman,* A Shropshire Lad, Last Poems; *Ibsen,* A Doll's House, Ghosts, Hedda Gabler, An Enemy of the People; *Masters,* Spoon River Anthology; *Milton,* Paradise Lost; *Molière,* The Merchant Gentleman, A Doctor in Spite of Himself, Tartuffe; *O'Neile,* Desire Under the Elms, The Emperor Jones, Ah Wilderness, Strange Interlude, Anna Christie; *Palgrave,* The Golden Treasury; *Pope,* The Rape of the Lock; *Rimbaud,* A Season in Hell; *E. A. Robinson,* Tristram; *Shakespeare,* any of his plays, a group of his sonnets; *Shaw,* Candida, The Devil's Disciple, Caesar and Cleopatra, Saint Joan, Man and Superman, Marriage, The Doctor's Dilemma (Be sure to read the prefaces to such plays); *Sophocles,* Oedipus the King, Antigone; *Spenser,* Book I of the Faerie Queene; *Untermeyer,* Modern American Poets, Modern British Poets; *Whitman,* Leaves of Grass.

Category VII, The Arts (Music, painting, etc.): *Adler,* Art and Prudence; *Beaumont,* New Paths; *Brockway,* Men of Music; *Buermeyer,* The Aesthetic Experience; *Burchkhardt,* Civilization of the Renaissance; *Cheney,* Modern Art; *Ducasse,* Art, The Critics and You, The Philosophy of Art; *Edman,* Arts and the Man; *Ellis,* Dance of Life; *Ewen,* Pioneers in Music; *Faure,* Spirit of the Forms; *Fry,* Vision and Design; *Goethe,*

Literary Essays; *Gray,* The History of Music; *Hulme,* Speculations; *Huneker,* Variations; *James,* Picture and Text; *Lang,* Music in Western Civilization; *Mather,* Do the Arts Make for Peace?; *Nijinsky,* Nijinsky; *Read, Herbert,* In Defense of Shelley and other essays; *Roeder,* Man of the Renaissance; *Rolland,* Beethoven, the Creator, Music for the Man who Enjoys Hamlet; *Shaw,* The Sanity of Art; *Stone,* Lust for Life; *Symonds,* Renaissance in Italy; *Taylor,* Music Lover's Encyclopedia; *Tolstoi,* Tolstoi on Art; *Van Loon,* The Arts.

ENGLISH 113*

Student Reports

Categories 2–6

In order to reduce lost motion in the reports on the non-fiction categories, students are requested to keep the following questions in mind:

1. What is the author's *main contention* in the book?

It is to be supposed that an author has a purpose in producing a book. De Kruif, for instance, in "Microbe Hunters," traces the growth of scientific knowledge about bacteria and develops his thesis in brief sketches of the lives and contributions of some fourteen scientists. This main thesis the student should look for, try to comprehend, and express in his own language.

2. In what *specific ways* does the author support his main contention?

In "The Origin of Species," for example, Darwin advanced a hypothesis to account for the structural and physiological similarities among living species. What specific examples and experiments did he use to support this hypothesis? As English 101 is intended to show, all good writers support their statements by definite examples. What definite examples does your author use?

3. How do the *author's background and training* fit him to write such a book?

Few writers are really "authorities." A writer on medical matters, for instance, may not be in good standing among medical men because he writes for magazines glowing accounts of scientific work before the scientists themselves are willing to offer any claims. Darwin, on the other hand, was a sincere and painstaking observer who seldom allowed his theories to outrun his evidence. In order to judge the value of a book, therefore, it is necessary to know something about the author's qualifications. Any student who finds difficulty in obtaining such information should ask his instructor.

4. What do I think about the book?

The student's opinion, at this stage, is probably worth very little, but democracy allows even the ill-informed to hold some opinion, and such a tentative verdict the student is expected to reach.

* Sample of instructions given to students.

Coordination in the Teaching of Mathematics to Electrical Engineers

By L. V. BEWLEY

Professor and Head, Dept. of Electrical Engineering, Lehigh University

The increasing necessity for teaching more and higher mathematics to the electrical engineering student, to meet the growing demands of his profession, calls for the closest possible coordination between the mathematics and electrical engineering departments. The available time is so short, and the encroachment of other than scientific courses on the engineering curriculum so persistent, that maximum use must be made of the few semester hours which can be spared for mathematical instruction. The complete, or quasi-complete, isolation between engineering and mathematical instruction now so prevalent, can no longer be tolerated if minimum objectives are to be secured. Engineering departments not only should specify *what* they want taught to their students, but also, in a large measure, should indicate how they want it taught. Otherwise, two tendencies may develop: (1) too much emphasis on rigor (with its accompanying rigor mortis), at the expense of necessary coverage, and (2) excessive dilution through attempts to run the entire gamut of modern analysis.

The average engineer must, from necessity, regard mathematics as a tool rather than a philosophy. He studies mathematics for the use to which he can put it, rather than as an exercise in intellectual discipline. He rarely can afford the time to explore a branch of mathematics which does not apply directly to his work. It follows, therefore, that the engineer's college course in mathematics must hew to the line of strict engineering applications, and not digress into fields having a low utility factor.

Rigor is the essence of pure mathematics. But it is very time-consuming, and when carried to excess leaves little time for substance. For example, it is essential that the engineer know a little about infinite series, and be able to apply the usual tests to determine convergence, and recognize the conditions under which series may be multiplied, differentiated and integrated. But in an undergraduate course there is not sufficient time to establish these characteristics rigorously, and parts of the proofs must be glossed over, or accepted on faith. The pure logic so dear to the mathematician, his careful specification of necessary and sufficient conditions, his insistence on the exact way in which a limit is approached, and his great concern over existence theorems, can almost always be circumvented in engineering work because the physics of the problem supplies the assurance. Then the question arises, what happens in the case where a sharp mathematical distinction is the only safe-guard against error? These

cases occur so rarely in engineering, that the average engineer can hardly afford the time to be prepared for the contingency. The specialist, of course, will acquire the necessary foundation in mathematical rigor.

Those who daily observe engineering students realize how little of the mathematics they learned throughout the calculus has stuck to their ribs. By the time they have an opportunity to apply it in earnest in their engineering studies—about the senior year—they have forgotten much of it. There are three reasons for this deficiency: (1) Too much time elapses between the end of the courses in calculus or differential equations, and the application, (2) The mathematics was learned as an abstraction, as an end in itself rather than as a means to some end, and with little evident application to physical or engineering problems, (3) The ineffectiveness of young and inexperienced instructors in mathematics who have no background in engineering or physics, or who are not sympathetic to engineering needs.

The first fault is chargeable to the engineering and physics departments. Too many engineering instructors are afraid to use mathematics, either through ignorance, or fear that it will be beyond the grasp of the student. As a matter of fact, engineering students can absorb physical ideas through the medium of mathematics much better than is generally realized. And why not: their background at the end of the sophomore year is essentially mathematical. There is a strange and unreasonable aversion on the part of many teachers of sophomore and junior physics, mechanics, strength of materials, and kindred subjects, to using more than the barest possible amount of mathematics. Witness the bizarre graphical methods often used in beam theory to avoid a simple differential equation! Such aversion on the part of engineering and physics instructors introduces a "cooling off" period of about one year, as far as mathematics is concerned, during which interval the student never uses any mathematics more formidable than a few simple integrals. This convinces him that his study of mathematics was a waste of time, and he proceeds to forget it with astounding rapidity. As a means of preventing this it should be a cardinal feature in the teaching of mathematics to engineers, to coordinate the mathematics with pertinent and practical engineering applications. This can be done not only by raising the mathematical level of the collateral courses in physics, mechanics, heat engines, electrical circuits and machines; but also by using mathematical textbooks well filled with exercises illustrating engineering principles. Mathematics must be applied as it is learned, and frequently thereafter. Then it will be retained. Otherwise, a forgotten tool is a lost tool.

Just what mathematical subjects should be taught to the electrical engineering student, and when and where should they be taught? Traditionally, certain mathematical subjects are taught in the engineering courses, or at least repeated there. For example, *descriptive geometry* is always taught as a part of mechanical drawing, and *complex numbers* always forms the introductory chapter of a course on alternating current circuits. It is generally conceded that isolated mathematical subjects of particular interest to some engineering course can be put across more effectively if taught there, than if compartmented in, say, an all-com-

prehensive course in advanced calculus. Certainly *complex numbers,* and *harmonic analysis,* are so closely allied to A. C. circuit theory, *hyperbolic functions* to transmission lines, and *operational calculus* to transients, as to make a divorce unthinkable. If there is an engineering course in the curriculum on two-dimensional field problems, some instruction is necessary in partial differential equations, potential theory, double Fourier series, and selected portions of the functions of a complex variable, to include the Cauchy-Riemann equations, and the Schwarz-Christoffel transformation. These subjects comprise the analytical core of two-dimensional field theory, and are best taught in the field course itself, rather than in an allied mathematical course. However, certain other useful tools in field theory, such as Legendre polynomials (used in calculating the potential due to rings, circular plates and coils), and elliptic integrals (used in solving some of the problems resulting from a Schwarzian transformation), are best left in the course in advanced calculus.

Before proceeding with recommendations on the type and contents of a course in engineering mathematics best suited to the needs of the electrical engineer, it will be well to review briefly the different mathematics which he may have occasion to use, and to appraise their value to him. To that end we will discuss the various mathematical specialties from the points of view: where used in engineering, when required in the curriculum, whether best taught in a mathematics course or along with the engineering application, and the estimated amount of time which reasonably can be spent on the subject.

Dimensional analysis is of great utility in engineering. It provides an organized means of converting from one set of units to another, gives a check on the structure of equations, and in many cases permits the general form of a solution to be determined without making a complete analysis. It is desirable to introduce dimensional analysis early in the curriculum; say in the physics courses where the young student has so much distress converting from one set of units to another, and is never quite sure of himself. If he were required in all cases to make a dimensional check on his equations he would acquire a good engineering habit. Instruction in dimensional analysis should be a part of physics and engineering, rather than included in a regular mathematics course. A few minutes can easily be diverted now and then to teach its essentials.

Differential equations, without question, deserve first priority in the mathematical training beyond the calculus for electrical engineers. Indeed, every circuit equation is fundamentally a differential equation. The study of transmission lines and transients is impossible without them. Advanced machine theory, problems in skin and proximity effect, field theory, and in fact practically every aspect of electrical engineering, beyond the most elementary, are dependent on a working knowledge of differential equations. Differential equations can also be used (but rarely are!) to great advantage in junior year strength of materials courses and in fluid mechanics. Those used in engineering are, for the most part, confined to ordinary or partial linear differential equations with constant coefficients, and to the equations of Bessel and Legendre. They are not, as a rule, much needed before the senior year, but in preparation for that time should be taught by the mathe-

matics department in the first semester junior year immediately following the calculus. A half-semester three-hour per week course in differential equations is quite ample for the needs of the undergraduate electrical engineering student, particularly if the curriculum provides a subsequent course in operational calculus.

Determinants are used in circuit theory not only as an organized procedure for obtaining numerical solutions to network problems, but also to deduce important theorems. (For example, the employment of Cramer's Rule to find the relationships between Maxwell's potential and capacitance coefficients.) It is not necessary to devote a great amount of undergraduate time to the study of determinants. All that is generally necessary is to show how they may be used to solve simultaneous equations. Multiplication of determinants is of no particular importance in engineering, and need not be considered in an undergraduate course. If determinants are given in Freshman algebra, they will not be used much until the A. C. Circuits course in the Junior year, by which time they must be reviewed. If they are included in a first semester, junior course in advanced calculus, the first week of the course should suffice for their consideration.

Infinite series, to include the standard tests for convergence, addition, multiplication, differentiation, and integration of series; errors committed in stopping at a given term; expansion of functions by division, chain fraction, binominal series, and the Taylor series, and a few of the tricks for hastening convergence, are all that should be required. The emphasis should be on application rather than on rigorous definitions. The engineer will use series solutions to the differential equations of transmission lines in both the steady and transient states, in the study of vacuum tube characteristics, and in the solution of various problems having non-linear differential equations. Moreover, infinite series are a necessary stepping stone to the more advanced aspects of mathematics. Two or three weeks in a course on advanced calculus can be profitably devoted to infinite series.

Fourier series are used in A. C. Circuits courses for the harmonic analysis of complex wave forms; and thereafter in the analysis of the m.m.f. and flux distributions of electrical machines, the frequency spectrums of radio currents, transients on transmission circuits, and in numerous other applications. *Double Fourier series* find application in field problems and in the harmonic analysis of electrical machines. It is therefore essential that the student be given a sound understanding of Fourier series, not only so that he can analyze given wave forms, but also that he may recognize the conditions of symmetry which exist for different combinations of sine or cosine terms, and even or odd harmonics. The close and intimate use of Fourier series in engineering would seem to suggest that they be taught along with their engineering application, but there is the danger that only enough would then be taught to meet the exigencies of the moment. For example, the instructor in A. C. circuit theory is not likely to spend more time on Fourier series than will enable him to proceed with harmonic analysis. Matters of convergence, types of symmetry, and analytic treatment, are likely to receive short shrift. It is therefore recommended that approximately one week be devoted to Fourier series in the

advanced calculus course, immediately following the period on infinite series. Later on, in senior and graduate transient courses, and in communication network theory, the *Fourier integral* will be needed. It is perhaps best to leave its consideration until then, and to develop it in connection with its engineering applications.

Bessel functions are used more in electrical engineering than any other harmonic function, except the circular. They appear in the study of transients on long lines and in machine windings; in frequency modulation, cylindrical wave guides and cylindrical resonating cavities; in skin and proximity effect problems; and numerous other applications in electrical engineering. Closely associated with Bessel functions are the *gamma* and *error functions,* which appear in transient problems, and in the interpretation of Bessel functions. The error function is also used in estimating the electron distribution in vacuum tubes. Approximately two weeks might be devoted to the gamma, error and Bessel functions in the advanced calculus course, and this should include exercises in the use of different tables of Bessel functions, and an interpretation of the several different notations which exist for these functions.

Legendre polynomials and *zonal harmonics* are used in calculating the potential in space due to charges or currents having circular symmetry about an axis; such as a loop of wire carrying a current, or a charge on a flat disk. One week in the advanced calculus course should suffice for consideration of these functions.

Spherical harmonics are used in certain antenna problems and in the analysis of spherical cavity resonators. They are used rarely, if at all, in power engineering. It is not feasible to include them in an undergraduate course. Nor is there justification for including other than circular and cylindrical harmonic functions in the undergraduate curriculum.

Functions of a complex variable play an extremely important part in electrical engineering, and should have a first priority in any graduate curriculum. Taylor and Laurent expansions, and integration in the complex plane, are essential to the study of advanced operational calculus and transients. The interpretation of certain network theorems is best made by means of complex series and expansions. The Cauchy-Riemann equations and the Schwarz-Christoffel transformation are indispensable in the study of two-dimensional fields. Such fields constitute the bulk of those encountered in engineering. It is hardly feasible to include functions of a complex variable in a one-semester undergraduate course on the advanced calculus; but if two semesters are available, the essentials may be covered in, say, one-third of the second semester. In a graduate course, at least one complete semester is necessary, and if the more advanced aspects are to be considered, and proper emphasis placed on rigor, a two semester course is appropriate. However, if the undergraduate curriculum in electrical engineering includes a course in two-dimensional fields where the Cauchy-Riemann equations and the Schwarz-Christoffel transformation are made use of, they should be included as a part of the engineering course, as they are a part and parcel of field theory, and their development within the engineering course is both natural and effective. Since these transformations oftentimes result in elliptic integrals, it is advisable to include a brief consid-

eration of such integrals in the section on infinite series of the advanced calculus course. The Schwarz-transformation also leads to elliptic and hyperelliptic functions, but these latter are beyond the compass of undergraduate engineering work.

Finite difference equations find application in the study of the recurrent ladder and filter networks which occur so often in communication theory, of surges in transformer and generator windings, of the potential distributions across insulator strings, and other periodic lumped circuits. *Chain fractions* and other reiteration methods appear in the analysis of the same circuits. These methods are best introduced and developed in connection with their engineering applications, as they are not mathematically complicated, and are most conveniently associated with the physical aspects of the problems to which they apply.

Graphical, tabular, and *machine methods* for the numerical solution of algebraic, non-linear differential equations, and the integration of complicated functions are of great utility in engineering. Typical examples are: determination of the roots of the characteristic equation of a transient problem, alternator swing curves in system stability studies, the characteristics of vacuum tubes, the behavior of saturable magnetic circuits, and some problems in antennas. Methods employed for effecting numerical solutions are best introduced in the engineering courses where they are encountered.

Operational calculus is the indispensable tool for the calculation of electric transients. In a large measure it has been developed and promoted by electrical engineers, and courses in it are so intimately connected with electric transients as to make their separation unthinkable. There are three ways in which operational calculus may be developed for the electrical engineer: (I) The direct operational method of Heaviside as set forth in his books, and exploited by others. The method has the advantage of simplicity, close association with methods of superposition already familiar in engineering analyses, and a considerable established literature. However, it has the great disadvantages that it lacks rigor, sometimes leads to erroneous results, and is awkward to use if other than quiescent initial conditions are introduced. (II) The Laplacian transform, which provides a rigorous solution through the agency of an infinite integral, and which is easily and naturally adaptable to the inclusion of other than passive initial conditions. From it all of the processes of the direct operational method may be developed, and in addition the pitfalls of that method avoided to a large extent. (III) The contour integral, resting on the theory of functions of a complex variable, which is the most powerful of all the methods, but whose application depends upon considerable mathematical background and facility. The more complicated problems requiring this method are generally beyond the scope of an undergraduate's mathematical experience.

Vector analysis is suggested as a most important branch of mathematics for the graduate electrical engineer; not because he will make much use of it *per se* in engineering, but because it introduces him to the principal theorems of mathematical physics, and opens the door to modern theoretical physics—electromagnetic theory, elasticity, hydrodynamics, analytical dynamics, relativity, etc. However, there is a growing tendency to make more use

of vector methods in engineering. For example, the calculation of the energy in a radiation field by the Poynting energy vector. A three hour per week course for one semester is quite adequate, and a great deal can be accomplished in less time. It is best offered as a graduate course, or as an elective for qualified seniors. If a second semester advanced calculus course is available to the undergraduate, perhaps one-third of the semester may be allocated to vector analysis.

Higher algebra, to include determinants, matrices and the theory of equations, is becoming more and more essential in advanced network theory and transients. Its theorems are necessary in higher circuit theory. It is usually offered as a one semester graduate course in mathematics.

Matrices and *tensor analysis* are of growing importance in engineering. In the advanced theory of networks and machines, wherever simultaneous equations must be manipulated, coordinates transformed, or massive generalizations effected, these tools are the most powerful available. Moreover, they provide a bridge between engineering and the modern concepts of theoretical physics and differential geometry. It is not advisable to attempt to introduce them to the undergraduate, but to offer at least a one-semester course in matrices and tensor analysis for the graduate electrical engineer. This course in the mathematics department can be closely coordinated with a two-semester engineering course in applications to circuits and machines.

The *integral equations,* or more properly the *integral-differential* equations, encountered in electrical engineering are either of the type which are immediately reducible to differential equations (as in circuits containing inductance and capacitance), or else of such complicated structure as to necessitate a graphical or calculating machine solution (as in the analysis of the oscillations of synchronous machines, and system stability studies). There is little justification for integral equations at the undergraduate level, or even at the graduate level, of an engineering curriculum unless a student is specifically interested in some problem involving them.

The *calculus of variations* would seem to have many possibilities in engineering work, but so far as I know, there are only two papers in electrical engineering literature which have used that calculus, and in both cases the application did not go beyond the formulation of some integrals and the interchange of differentiation and variation. Incidentally, the results of both papers are derivable by simpler means. Perhaps someday the power of the calculus of variation will be recognized by engineers. But certainly if it intrigues some young genius, it will be only after considerable study at the graduate level. The smattering of the subject given in some texts on the advanced calculus is hardly worthwhile.

The *theory of errors and probability* is important to the telephone engineer, and to those engaged in quality control of manufacturing processes. But its field of application to electrical engineering is too specialized and restricted to justify its inclusion in an undergraduate mathematics course. The engineer thrown in contact with a problem requiring its use will not find much difficulty in acquiring a working knowledge of the subject within reasonable time.

Table I indicates the chronological

TABLE I

INCIDENCE OF MATHEMATICS IN ENGINEERING

	Engineering Subjects	Mathematical Subjects	
		Engr. Dept.	Math. Dept.
Fresh.	Engineering Drawing Physics (mechanics)	Descriptive Geom. Dimensional Analysis	Algebra Differential Calculus
Soph.	Physics (heat, light, elec. sound) Statics and Dynamics D.C. Circuits and Machines		Int. Calculus
Junior	Strength of Materials Fluid Mechanics Heat Engines A.C. Circuits A.C. Machines	 Complex Numbers Harmonic Analysis	Diff. Equations Partial Derivatives Determinants Infinite Series Fourier Series
Senior	Transmission Lines Radio System Stability Elec. and Mag. Fields Transients	Hyperbolic Func. Numerical Integration Double Fourier Series Potential Theory Cauchy-Riemann Eqs. Schwarz-transformation Operational Calculus Laplace Transform Fourier Integral Finite Diff. Eq. Numerical Solutions	Bessel Func. Legendre Polynomials Elliptic Integrals Gamma Function Beta Function Error Function
Graduate	Advanced Transients Electromagnetic Theory Adv. Radio and Electronics Advanced Networks Advanced Machines		Func. Complex Variable Vector Analysis Partial Diff. Eq. Cylindrical Harmonics Spherical Harmonics Matrices Higher Algebra Tensor Analysis

incidence of mathematics in an electrical engineering curriculum, and suggests whether a particular phase of it is better taught along with its engineering application or in a separate mathematics course. It is neither feasible nor desirable to arrange for the teaching of isolated mathematical subjects so as to synchronize exactly with their utilization in engineering courses. All such undergraduate material should be consolidated in a one or two semester advanced calculus course given in the junior year. The graduate mathematics will require considerably more time and distinct courses.

Recommended Mathematical Courses for the Electrical Engineer

The foregoing appraisal of the different mathematics of most use in engineering suggests the contents and scope of a course in engineering mathematics to follow the calculus.

If only one three hour per week semester is available for the course, it is believed that maximum benefits will derive if it is arranged chronologically approximately as follows:

Determinants	1 week
Infinite Series	3 weeks
Fourier Series	1 week
Differential Equations	8 weeks
Gamma, Error, Bessel, and Legendre Functions	3 weeks

To try to do more results in too much dilution. The above constitute the most used and important subjects in engineering application.

If a second semester can be devoted to engineering mathematics, it might comprise:

Partial Differential Equations	5 weeks
Vector Analysis	5 weeks
Functions of a Complex Variable	6 weeks

During recent years a number of text books have appeared on the market which recognize the advanced mathematical requirements of the undergraduate engineer. They provide essentially the same coverage as outlined above, but their arrangement is different. However, they are written in such fashion that the instructor may take up the different subjects in any way he pleases.

For graduate work leading to the master's degree, the mathematical requirements are more stringent, and individual wishes more specific. But an excellent combination which will fit the mathematical needs of most graduate electrical engineering students is the following:

1st Semester

Higher Algebra and Matrices	(3)
Functions of a Complex Variable	(3)

2nd Semester

Tensor Analysis	(3)
Vector Analysis and Partial Differential Equations of Mathematical Physics	(3)

The (3) refers to semester hours.

The above combination coordinates perfectly with the mathematical requirements of the usual graduate engineering courses in either Power or Communication. For example:

Power Option

Advanced Machinery
Application of Matrices and Tensors to Circuits and Machinery
System Stability
Advanced Transients
Theory of Elasticity

Communication Option

Advanced Radio and Electronics
Advanced Network Theory
Electromagnetic Theory

It will be noticed that identical mathematical courses, totalling twelve semester hours, are recommended for either the power or communication option.

It is contemplated that the course in *higher algebra* will provide the necessary foundation in determinants, matrices, theory of equations, and the concepts of forms, invariancy and group. This material is used in advanced network theory, and in the application of matrices and tensors to electrical circuits and machinery.

The course in *tensor analysis* must include non-holonomic transformations of the Christoffel and Riemann curvature tensors, and the tensor expressions

of the theorems of mathematical physics.

The course in *functions of a complex variable* should cover complex series, Taylor and Laurent expansions, residues, and integration in the complex plane. The material is used in advanced transients, networks, and radio.

The course in *vector analysis* and the *partial differential equations* of *mathematical physics* might very well devote half of the time to each subject. The subject matter is used in radiation and antenna theory. Moreover, the student is then equipped for future reading and studies in the field of theoretical physics.

Conclusions

The opinions which have been expressed in this paper may be consolidated in the following conclusions:

1. The average engineer cannot afford the time to study mathematics which will not prove useful to him.

2. The engineer is interested in mathematics as a tool, rather than as a philosophy; and he is therefore more concerned with application than with excessive rigor.

3. Mathematics should be applied in the physics and engineering departments as it is learned in the mathematics department, if it is to be retained and exploited for maximum benefits.

4. It would be a boon to both mathematics and engineering if the mathematical level of junior year engineering were raised materially.

5. Mathematics must be taught in time to be used, but it is a mistake to prepare for it too far in advance—it is too readily forgotten and time must be used to review it.

6. Except for isolated cases, like complex numbers, mathematics should be taught in the mathematics department by mathematicians who have an engineering point of view.

7. The mathematics taught in an advanced calculus course for engineers should be carefully budgeted and screened to meet strict engineering needs, and the cramming in of relatively superfluous material should be avoided.

8. The mathematics given to graduate students must be just as carefully selected as for undergraduates; although entire rather than composite courses should be provided.

9. It is a great advantage to have a mathematics instructor assigned to the engineering department, where his work can be more closely coordinated with the engineering courses, and where he can be required to teach exactly what is needed when it is needed.

10. If special mathematics instructors cannot be assigned to the electrical engineering department, then close and constant liaison is necessary between the two departments. For a small department, this liaison is best effected by direct conferences between department heads. For a large department, a committee arrangement may be better.

After Veteran Programs, What Next?*

By HERBERT L. SPENCER

President, Bucknell University

I have been asked to talk on the subject "After Veteran Programs, What Next?". Some one, I fear, has attributed to college presidents, and to me in particular, a gift of prophecy to which I cannot honestly lay claim, much as I would like to do so. Actually, the recent trend of international affairs, particularly the events of the past few weeks, may well give rise to the question, "Will we ever be without veterans —and veteran programs?". Perhaps it's just my characteristic optimism, or the fact that today is the first day of spring, but I, for one, am looking forward to the day when war—and hence veterans—will be a thing of the past.

If I were to confine or to limit my talk entirely to the topic as expressed, I should probably have to say that the veteran programs are primarily financial programs. We make no academic distinctions in the education of veterans and that of non-veterans. Therefore, I would be required to delimit my talk to a prophecy of financial arrangements which might be made for students after the present veterans' program has finished. I am sure, however, that you do not want me to restrict my talk to such a narrow topic.

First, therefore, let me speak only briefly on the financial side of higher education. We all know the great demands that have been made upon our colleges and universities due to the huge enrollment of veterans. There are many students, and even some faculty members, who have the erroneous idea that now that we have large student bodies, all of our financial problems are solved. As a matter of fact, quite the contrary is true. I believe that any college business manager can show you that, with the mounting high costs of maintenance and repairs and with the continuing decrease in return on endowments, the financial plight of our colleges is more crucial than formerly.

Dr. Henry T. Moore, President of Skidmore College, in his annual report to the trustees of that institution, pointed out several days ago that the college dollar of 1940 had shrunk to about 70 cents. Other colleges, I am sure, are faced with this common dilemma—how to maintain the quality of their instruction without increasing student fees to an extent which might work a severe hardship upon many of their students.

Our concern with the problem of balancing our college budgets should not be allowed, however, to blind us to the necessity for planning how we can finance worthwhile students after the veterans' program. Before attempting to answer that question, perhaps it would be wise for us to try to

* Presented at the meeting of the Allegheny Section, A.S.E.E., Carnegie Institute of Technology, March 21, 1947.

estimate how many students will be going to college after the peak of veteran enrollment has passed.

Many predictions have been made regarding college attendance in the post-war period. All of these studies point to a continuation of high enrollments in colleges and universities even after the G.I. benefits have ended. These estimates are predicated primarily upon the increase in population in the United States, and upon the stimulation given to higher education during the war. The established pattern of federal support to individuals for higher education cannot easily be dropped. All predictions, therefore, indicate that there will be a much larger number of students entering our colleges in the future than we have seen in the past. This means that either our colleges and universities must become larger, or we must establish more institutions of higher education.

Let us examine more of the figures which support this statement. This organization, the American Society for Engineering Education, estimated last spring that the maximum capacity of the engineering colleges was around 155,000, an increase of 37 per cent over the pre-war peak of 113,500. The committee making this study estimated that freshmen would constitute 36½ per cent of the total enrollment; this would mean a freshman class of 56,500 in our engineering schools.

In an article appearing in the March 1, 1947 issue of *Higher Education*, and scheduled to appear also in a future report of the American Society for Engineering Education, Henry H. Armsby states that "the enrollment in engineering colleges as of November 5, 1946, was about 223,000, including more than 92,500 freshmen." This represents an increase in total enrollment of 340 per cent over that for 1945, or 197 per cent of the previous peak enrollment, and 144 per cent of the estimated maximum capacity. These figures are estimates which were made by comparing enrollment reports from 90 institutions with previous reports from the same institutions, and from all engineering colleges. These reports are collected annually by the American Society for Engineering Education. The united reports for 1946 were made available in advance of publication by the secretary of the Association for use in this study. Mr. Armsby goes on to summarize this report as follows:

"The salient facts in the study are summarized in the accompanying table which compares the estimates just mentioned in the enrollments of all colleges and universities, including the engineering, as estimated by the Research and Statistical Service of the Office of Education from the sampling survey, the results of which have been published in mimeograph form as the Statistical Circular SRS–21, 3–116. According to this report, the total 1946 college enrollment is about 2¼ times that of 1945, while the engineering enrollment is nearly 3½ times that of 1945. The number of men in all colleges has been multiplied by about 3⅞, in engineering by 4¾. The enrollment of women increased slightly in all colleges, but decreased in engineering. The small number of women students in engineering distorts the ratio of veterans, since veterans include members of both sexes."

Year	Total undergraduates	Engineering students
1900	237,592	15,000
1910	355,215	21,771 (1909 figure)
1920	597,880	52,144 (1922 figure)
1930	1,100,737	73,386
1940	1,494,203	103,270

We do not have available at the present time an accurate statement regarding the total number of undergraduate students in all of our colleges and universities. The predictions are that it will exceed 2,000,000, with about 223,000 engineers, as reported in Mr. Armsby's article quoted above. The indications are that enrollments in our engineering schools will remain high for some time to come. I do not believe that we have now or ever have had a surplus of really top grade engineers. We did have before the war an excess of technicians and I believe very soon our labor market will be flooded with this type of engineer.

Not all of these students who will be coming into our engineering schools will be in a position to pay all of their own bills. What assistance can they logically expect? I predict that we shall have state and federal scholarships at large given to needy students who have shown by their high school records and by the results on a battery of prognostic tests that they have the ability to pursue successfully an engineering education. I believe that these scholarships will be granted to students for both undergraduate and graduate work. Certainly, modern civilization of a democratic nature cannot continue with half the people of superior mental ability unable to go to college because of financial limitations.

In a very challenging document published by the government not so long ago entitled, "Science, the Endless Frontier," there was set forth a strong argument for the establishment of a new federal agency, the National Science Foundation. Several bills, such as the Thomas Bill, S.525, the Smith Bill, S.526, the Celler Bill, HR942, and modifications of these bills such as S.1850 and S.1285, have been introduced in Congress recently in the support of such a foundation. No doubt within the very near future we shall have legislation establishing a National Science Foundation for the purpose of supporting basic scientific research in the universities and colleges of the land. Most of these bills also include funds for scholarship aid. Comparison of the various bills supporting the establishment of a National Science Foundation can be found on page 253 of the March 7, 1947 issue of *Science*.

But the problem of financing the education of future engineering students is not the only one which faces us today. Even more urgent, perhaps, is the task of trying to foresee the sort of world in which these future engineers will be called upon to serve, in order that we may determine how best we can prepare them for their part in our new civilization.

The turn in international affairs during the past week leads us to the question, "What next?". If we do not find a new approach to the problems of international relations, the factor most important to everyone in the world today, the answer may be "Nothing." I say this in all earnestness. If complete world chaos and anarchy, if not complete annihilation, are to be avoided, we had better put our shoulders to the wheel right now for a lot of hard work, and we had better open our eyes and incline our ears to the ground to see if we can pick up the sound of the footsteps of tomorrow's people, or perhaps to catch the accents of God's voice.

Let me read you something from Lewis Mumford's book, "Values for Survival": "'At the present rate of progression since 1600, it will not need another century or half century to tip thought upside down. Law, in that case, would disappear as theory or a

priori principle and give place to force. Morality would become police; explosives would reach cosmic violence. Disintegration would overcome integration.' These words were written by Henry Adams in a letter to Henry Osborn Taylor in 1905, and he elaborated them in his essay on 'The Phase Rule in History.' 'The age of atomic energy opened with A. H. Becquerel's discovery of radio-activity in 1896. With the invention of the first machine for releasing atomic energy on a large scale (the atomic bomb itself) that age has possibly, already, almost reached its end. If we fail to establish the necessary political controls and to impose the necessary moral disciplines, our world will come to a close in a quick orgy of annihilation, drawn on by unsupportable anxiety and fear.' "

Mumford also says, "But if we learn the art of control soon enough to prevent the suicidal misuse of scientific knowledge, we will by that very fact have outlived the atomic age itself, the age of unqualified indiscriminate power. The unification of knowledge and light will put an end to the current pursuit of power divorced from the end of life. In the very act of saving the race, man will be compelled to master the perverse impulses that repress life itself; and that conquest will make the atomic age, in which the machine dominated and threatened the existence of man, obsolete."

Events of recent days indicate that we, the people of the United States, are about to take a definite step in the right direction. We have found that England can no longer serve as the bulwark of western civilization. Someone else will have to take over in her place. Unless we become the champion of Christianity against the forces which threaten it, Russia will take over the rule of the world. Our recent stand is a challenge to the world that we no longer will support an appeasement policy as we did when the Japanese invaded China, when the Italians invaded Ethiopia, and when the Germans invaded Austria and Czechoslovakia. Russia today is not strong, but she could and would become strong if we allowed her to go along assuming control in one nation after another. Russia could become strong that way just as Hitler's Germany became strong by following a similar policy. War with Russia would be less likely to follow under the new policy which has been outlined for us. Russia will instead, I believe, become more interested in a functioning United Nations. This would mean world peace instead of another world war.

There is a price, however, which we must pay for assuming world leadership. Our government estimates that it will cost us $30,000,000,000 if we are to make our plans go through. It will require not only capital, but capital equipment in a large volume; also great quantities of food and clothing, and what is more, brains—engineering brains—to make our investment work. This is a definite challenge to our engineering schools, a challenge which cannot be met by our continuing subservience to a narrow scientific and technical curriculum.

The scientific age has brought about a great demand for engineers who are qualified for the whole range of managerial positions extending from supervisors through executives to top administrators. What is the best way to prepare men for such responsibility? Should it be narrow training or broad training? This is an issue much in dispute among educators. Certainly we cannot expect that our young engineers can take over executive and other

responsible positions without experience. According to Dr. Robert D. Cawkins, Dean of the School of Business of Columbia University, "The issue is between specialized training intended to qualify the student for a job upon graduation, with but secondary attention to his subsequent needs, and a broader and more fundamental sort of preparation that is intended to develop the basic qualifications of the student to prepare him for later responsibilities. The issue is between training for a job and training for a career." The first is the function of the technical institute, the latter the "number one must" for the modern engineering school. Such training properly given by the engineering school offers greater long-run rewards and does not really deprive the student of a job upon graduation.

It should be recognized that at the present time no clear-cut line can be drawn between what is known as engineering education and technical education. Neither can we draw a clear-cut line between the advanced work of vocational education and technical education. Many of us are aware of the disputes encountered during the war between the Engineering Science Management War Training program and the Vocational Education Training program sponsored by the U. S. Office of Education. The main differentiation at the present time between the technical education and engineering education appears to be the amount of training required: the technical program requiring one or two years, and the professional program of engineering four to five years beyond high school. The main difference should be not only in the quality of work and in the ability of the student to pursue such work, but also in the emphasis placed upon major objectives.

Our experiences with the Engineering Science Management War Training program indicate that where one position exists requiring an engineering degree, anywhere from one to six positions exist requiring less than two years of concentrated practical technical training. The engineering school of the future should not waste its time on training for these sub-professional jobs.

This leads me to the prediction as to the type of educational programs that our engineering colleges should sponsor. In the first place, I believe that the pre-professional, or technical-institu type of education should be the function not of our recognized engineering schools, but rather of separate organizations, such as the so-called technical institute, established by either local or state governments, for the purpose of training draughtsmen, surveyors, chemical assistants, and for other semi-professional positions. Engineering education should be highly selective in its outlook. Only students of superior mental ability and personality traits should be allowed to enter our engineering colleges. The increasing cost of maintenance and the decreasing return on endowments make it imperative that we spend our money for those who have the ability to profit by it.

We are guilty, I believe, of overspecialization in our undergraduate programs. I should like to recommend, especially for the smaller schools of engineering, a four-year program in general engineering in contrast to the highly specialized programs such as those in mechanical engineering, electrical engineering, civil engineering, and chemical engineering. Specialization in these specific fields should be reserved for a fifth year.

This program of general engineering

should be much broader than the present program and should place greater emphasis on so-called humanistic studies. All of us need the humanizing influence of philosophy and art, plus a broad background of social studies, mainly history, sociology, and economics. It is not enough to know how to do something; we must know why we do it and what we hope to accomplish. Familiarity with a past is absolutely essential if we are to have a part in plotting the future. Global geography must become more than a mere label; it must become a part of our basic knowledge.

A knowledge of economics, for example, might have prevented the impossible situation which has developed in Korea. An illogical division of that country between Soviet and United States occupation forces placed under Russian rule nearly all of the nation's industrial resources, and under U. S. rule practically all of Korea's agricultural resources. As a result, we are now faced with the problem of industrializing our occupation zone with equipment and supplies paid for by American tax-payers.

To say that engineers must develop the art of communication—the ability to speak and write intelligently—may come as a surprise to many who do not realize the extent to which some of our engineering graduates are lacking in this requisite. The engineer who hopes to be more than a mere mechanic, to become a builder in the true sense of the word, must be able to explain his ideas and to convince others of their soundness.

If we are to resolve the conflict between capital and labor, the most vital problem in the whole engineering field, our undergraduate curriculum must place greater emphasis upon human engineering—the science of human relations. No engineer who hopes to reach a top position can expect to do so unless he develops a deep understanding of the motives which prompt men to work and to achieve. Henry Ford II, because of his humanistic approach to the whole problem of industrial relations, is probably the country's leading young business man of today. It is interesting to note that Ford began the study of engineering as an undergraduate at Yale, but switched instead to sociology, because he found engineering courses too dull.

We can expect an increase, also, in graduate engineering work in response to the demand created by the expanding fields of science. Recent developments in biological, chemical, and physical sciences will attract many young men who will find it possible to continue their education since so much of their undergraduate work was made possible through their veterans' allowances. More and more we shall see our engineering schools devoting more time to graduate work and to research.

It is unnecessary to point out that the present curricula in undergraduate education have been subjected to great criticism. A Committee on Undergraduate Curricula of the American Society for Engineering Education is seriously studying the present program with a view to making definite recommendations for changes. This Committee, under the chairmanship of Dr. Webster B. Jones, director of the College of Engineering and Science at the Carnegie Institute of Technology, will report at the annual meeting of our society in Minneapolis on June 19th.

The report of this committee will be very broad, covering not only the aims and objectives of engineering education

but also a complete study of the student and faculty load, teaching methods, and physical equipment. The study will also make reports on methods of admission. The Committee will also try to answer such questions as:

1. Should the prospective engineer be required to take a year or more of humanistic studies before entering an engineering college, as is the case with law and medicine?

2. In an engineering curriculum, what should be the proportion of basic science (mathematics, mechanics, physics, and chemistry), technological (specific courses in a department and related courses or service courses in kindred departments—such as courses in mechanical engineering for electrical engineers), and humanistic studies (English, history, economics, psychology, philosophy, languages, and like subjects)?

3. Should the humanistic studies be distributed uniformly throughout four years, or should they be concentrated in one or more semesters?

4. Should engineering be a four- or a five-year course?

5. In some quarters there is a growing feeling that in the past curricula have contained an excessive amount of purely informational matters. How much of this sort of material should be included in the technical courses?

It is easily seen that this committee believes that technical competence is not enough. Technical competence alone may give a graduate a comfortable economic position, but it is not enough to bring ultimate success and true happiness to the real engineer. What is needed most in our engineers is leadership. Leadership requires thought, courage, and discernment. No engineer can aspire to great heights unless he is acquainted with such fields as literature, business, law, religion, and local, state, national, and international affairs. We shall look forward to the report of this committee in June. No doubt, they will give us the answer to the question, "After veteran programs, what next?".

The Engineer and His Place in Research*

By ALLAN R. CULLIMORE

President, Newark College of Engineering

First I think perhaps some observations might be in order as to the general conception of research and its implications to the engineer. Some time ago it was suggested that it might be fruitful to divide the engineering field into functional divisions or groups, forgetting the traditional designations of mechanical, civil, chemical and electrical engineering, and considering the profession as divided into four major divisions or groups—first, that of research and invention, then design and construction, the third operation and management, and the fourth sales and distribution. This might enable us to make a somewhat different analysis from the traditional one with respect to research, and would allow us to consider, certainly, in our thinking, some basic considerations which are common to the general research field—or perhaps the general engineering research field as a broad concept rather than as a specialized one—and this might allow us to concentrate, perhaps, on the question of research irrespective of a somewhat rigid and formally divided field.

In attempting to be more or less fundamental in our concept of research, perhaps it is well to point out that while there still seems to be a considerable amount of argument concerning the differences between scientific research and engineering research, such a distinction seems hardly worthwhile following too far. Sometimes it would appear that in this connection the word "argument" is more descriptive of the actual condition than the word "distinction." It is notable that in a recent conference at Princeton several points of view were advanced, but it seemed to be the consensus of opinion—if this observer observed correctly—that a definition made by one group to draw a line of distinction between that group and another group, the other group already having a line of distinction so drawn, seemingly confuses, but does definitely cause an overlap so great that no definite line has actually been drawn.

It might be further observed in this connection that certain engineering researches are not capable of the classical and altogether rigid controls applied to the so-called researches of pure science. Engineering research perhaps touches life at many points and is certainly more difficult, because it involves certain factors, as Jewett points out, such as time, profit, and sometimes is conditioned by subjective factors which are extremely difficult but which do not appear in researches in pure science.

This is simply to indicate that certainly in the opinion of the writer,

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there ought to be no question as to the importance of research in the engineering field. The *applications* of science can, I think, be properly considered as a field for research and as fertile, but perhaps a more difficult field, than that known as the field of pure science unadulterated by engineering or any human benefits. I remember I heard E. L. Thorndike at one time say that in another field of measurement it was impossible to screen out and secure anything pure and that science and engineering could not exist in a pure state, that science had always in it potential practicability and that in the same way, engineering and applied science were absolutely dependent on fundamental knowledge of what might be called pure science. And then he went on to say that in some cases he had actually found mathematics adulterated and contaminated with a certain degree of common sense.

What to us seems important is to set up a means or a plan or an arrangement of our undergraduate and graduate work so that we can develop—or perhaps discover would be a better word—human material which is particularly adapted to research, and I think a thing that is just as important is to be able to detect that early enough so as to direct it in the right channel during the undergraduate years. Some plan or plans, some theories or hypotheses should be advanced with respect to this particular field. We all recognize the basic character of fundamental science in all engineering work. It is unnecessary to point it out here to this audience. It is difficult to stress too strongly the study of this fundamental science, characterized as it is by rigorous training, rigorous methods of thought, rigorous scientific control and training in the technique of scientific measurement and the scientific method. While we recognize the necessity of this thorough grounding, and while we give it, and while we test for it, and while we insist upon it, and properly so, we perhaps do not altogether realize the fact that we may be losing some values which in the field of research are basic and extremely important. Perhaps we do not realize that underlying all this rigorous and routine work of science there is a very important factor—important particularly in research—which is variously known as creative imagination, intuition, inventiveness, or genius—a quality which is characteristic of what we call real research. While it is perhaps true that our leading research men have been born that way, it is nevertheless true that such students can be discovered, they can be stimulated, and they can be properly conditioned, and if this is not done, students may not only not be trained, but may be entirely hidden and never emerge.

This thing which we have called by various names such as inventiveness, intuition, imagination or genius is not only a part of formal research as we understand it, but is the very stuff of which creative reflection or thought is made, and the really great engineers who have emerged, even under our present system, are characterized by a power to think, a persistence of certain techniques, certain points of view, certain methods of attack, certain capacities to proceed on their own—a certain dynamic intellectuality which proceeds as research proceeds, and this is the thing for which we must look. In graduate work today we are sensitized to it. Our professors in our graduate schools realize its advantages and are looking for it, and the advantage of an advanced degree in research lies not only in the possibility of pursuing

courses which lead well below the surface of science and in which there is more time to get into the heart of the thing, but it does bring the individual in smaller groups into an atmosphere which is sensitive to the needs of research. In an undergraduate curriculum which has been filled to overflowing with technical work in the upper years, many of our men, sometimes upper classmen, are snowed under—not by science, but by technological application—and it seems to me over the whole picture fail to get enough basic science. American undergraduate education appears somewhat superficial in this respect compared with the English and Continental types. The American student seems to suffer because he has too much choice among many superficialities, and compared with his overseas friends, he seems to lack the ability to pursue basic and sustained projects as an undergraduate. As a graduate student, these differences tend to disappear, and at the end there may be little difference between the capacities of the holders of the doctors' degrees here and abroad.

The one phase, however, which the writer wants to stress here and which has interested him over a long period of time is the possibility of determining research material in the undergraduate field. In the early years of undergraduate college life it is, of course, possible to pick out students who are successful in repeating what has been taught to them and putting down the things which they have learned from books in the routine matters of scientific experiments and substantiations and in the application of the formulas to the problems of the engineer and applied scientist. These students may, however, lack any spark of creative imagination, intuition, genius, or whatever you are pleased to call it, which is characteristic of what we are pleased to call real research; but are we in any considerable degree sensitive to the young man who possesses something of the unique, something of the inventive? As I remember it, a story was told about George Westinghouse that he was advised to leave college because he had some of these qualities, and I would submit that at the present day times have changed to such an extent that if Westinghouse had managed to get into a graduate school, which he could not have done unless he had been discovered, he might have contributed even more to invention than he did.

As a technique of stimulation very considerable work has been done by assuring contacts in the later years of a student's life, particularly in the graduate years, with some professor who has had some experience with and some sensitivity to research, and who is interested in the recruitment of research personnel. It is very important, of course, in graduate work, that means be given and some definite place be set apart where there may be interchange of opinion in small groups where men can meet and discuss their technical problems and where there can be a free interchange of ideas. In such situations it is not beyond possibility—in fact, it is very likely—that a fertile imagination or a fertile intelligence is recognizable. It certainly is true that the spirit of real research proceeds by stimulation and is a group function rather than an individual function. At least, it takes a group to stimulate and bring out ideas which may seemingly be original but which are withdrawn, it seems, only in the reception of other ideas. There should be some influence stemming, I think, from our *undergraduate* curricula to uncover the sort

of thing which is perhaps the most valuable attribute in our field—that capacity to recognize the pertinent and discard the impertinent, that rare capacity to understand relationships and to formulate hypotheses.

While the stimulation of our students is important, of no less importance is the stimulation of the younger instructors as well.

The practical difficulties connected with this stimulation are the practical difficulties which always arise when the question of stimulation in any field is talked of. Frequently the tools—and in this case the very precise tools—of scientific calculation are lost sight of, and in this process of stimulation we begin unconsciously to play down somewhat our precise and rigorous techniques. It requires some considerable experience and some background to stimulate and not to overstimulate—to stimulate this question of ingenuity, inventiveness, and imagination, and at the same time to retain relative values and the balance necessary to a scientific procedure. There has been, of course, much written on various methods of stimulation looking toward the development of creative thinking. These have been rather unfruitful, perhaps because most of us when we get an idea seem to have to go off the deep end on it, and if we speak of imagination, we feel that we must in some way oppose emphasis on rigorous procedure.

This is one of the cases, it seems to me, where the most delicate balance is needed, which involves your student material on one hand, and the man skilled in the technique, the procedure, and the philosophy of research on the other. In the hands of anything except an experienced man, such an attempt at stimulation usually involves an amateurish attempt on the part of the instructor to oversimplify some of the more subjective and intangible values in the problem.

No matter how we view the situation or how long we have been in engineering, we must appreciate and face the situation that research occupies quite a different place in the engineering picture now than it did thirty or even twenty years ago, and perhaps on the part of some of us who are older, we did not come to realize soon enough the importance of this broad field of work. In a certain sense, as I remember my own engineering education, it partook to a considerable extent of work which we would now call vocational, but which then was considered to be very highly professional in its character. I am not sure that all of us who spend a major part of our time in instructing youth have altogether a full and complete conception of what this question of research implies. Perhaps the problem itself is one for research, and it would certainly be solved, if we can solve it, by a study of the modern needs for the training and development of research personnel, by the studying and the analysis of such observations as have been individually made, and by the formation of various tentative hypotheses which will vary very widely in the many institutions of the country—all the way, perhaps, from the preceptorial system to formal seminars; and out of these various hypotheses there may come—and I think there will come—a procedure which will be perhaps better than any other which we at present adopt. The continued modification and substantiation of these hypotheses which we individually and as institutions hold is distinctly a problem of research in the proper sense. The

only thing that we can hope is that this research will not be characterized by some of the bigotries and intolerances and prejudices that have dogged education for many centuries.

I am frank to say that in my own case it seems to me that the greatest good can be accomplished by attempting to sensitize the younger instructors to some of the values inherent in research. I remember that not long ago one of our most noted professors in chemistry insisted on teaching freshman students. If this could be done, and if we had enough noted professors to teach younger students, we would have almost an ideal situation, but it seems to me at the present that the greatest thing we could do would be to attempt to sensitize these younger men to the requirements which research imposes. The facts seem to be that a very large proportion of our laboratory work is given by a group of younger men. Much of this work is rigid in the extreme. Laboratory manuals have been so carefully prepared that the student—even the most foolish one—cannot go astray, and I should like to submit that there is a place in the thinking of these younger men for the idea of some creative initiative on the part of instructor and student alike.

In a way, research is thought and thought is research. We are not doing too much to teach our students to think for themselves. The spirit, the philosophy, of research, could help us so much on the undergraduate level. It almost seems as if we have seen the great need for that spirit to animate our engineering teaching, and then set up barriers which make it too difficult for even the most adventuresome instructor to deviate from a system which makes much of our laboratory work sterile.

Could we not at least present to our instructors a clear picture of the method of science—how it proceeds and to what ends? It would not, it seems to me, be so difficult to determine some method by which all of our laboratory instructors could meet in small groups, learn to know each other, and sometimes have the privilege of examining and suggesting ways and means to utilize the spirit of research in their own teaching, led occasionally by a man who really knows research.

In a word, I believe that the greatest results will be attained when we not only allow our younger men to apply some research techniques, but when we place upon them responsibility to discover some trace of it in others. Perhaps, to paraphrase the words of Thorndike, we might contaminate science with a little imagination, and we might be very far along by so doing. At least, it is my confirmed opinion that to work on the youth in our faculties presents the greatest opportunity for lasting good along these particular lines.

I am tempted to close upon a rather personal note. Many of us—and I think *too* many of us—never have a real inspiration, and I think that perhaps that is not altogether our fault. In fact, I never attended but one series of classes which were frankly designed to be inspirational, where it was expected of us that we say something that we had never heard before—something that had never been put into our mouths or eyes or ears; where we were required not to memorize nor repeat, but to get something which was new; where there were questions asked to which there was no known answer. I think that this course that I took when I was about eighteen, was the most rigorous, the most constructive, the most inspirational course experienced in my life.

George F. Swain had not the reputation of being slipshod. The most interesting thing about it was that when Mr. Lamme of the Westinghouse Electric and Manufacturing Company offered a medal for the best teaching in engineering in the United States, my teacher was the first recipient of that medal. Perhaps there is a lesson for all of us in this.

Proof of the Kelvin-Helmholtz Equation for the Equilibrium Vapor Pressure above a Meniscus

By WINSTON O. SMITH

West Lafayette, Ind.

Although a number of proofs of the equation for the equilibrium vapor pressure above a meniscus have been published previously, the following may be of interest because of its comparative simplicity.

The pressure of the liquid in a drop or under a convex meniscus is greater than that of the surrounding vapor, and the converse is true in the case of a vapor bubble or a concave meniscus. For given values of radius and temperature there is a unique value of the vapor pressure for thermodynamic equilibrium. For example, if the vapor above a concave meniscus is at this equilibrium pressure, the liquid level will remain constant. If the vapor pressure is less, the level will decrease as the liquid evaporates.

For the purpose of analysis assume the isothermal cycle shown below.

"A" is an evaporator with flat liquid surface, and "B" is a condenser in which the liquid surface forms a meniscus. The flow of work and heat is as shown in the diagram.

Applying the general energy equation to the pump:

$$p_1\frac{v_1}{J} + e_1 + {}_1Q_s = p_s\frac{v_s}{J} + e_s + \frac{{}_1W_s}{J}.$$

Assume e = constant; ${}_1Q_s = 0$; and that the fluid is incompressible. Then the external work for the pump becomes

$${}_1W_s = -v_s(p_s - p_1). \qquad (1)$$

Now if we assume that the vapor is a perfect gas (very nearly true for most low pressure vapors), the external work for the turbine is

$${}_sW_2 = \frac{RT}{M}\log_e\frac{p_s}{p_2} \qquad (2)$$
$$(p_2v_2' = p_sv_s').$$

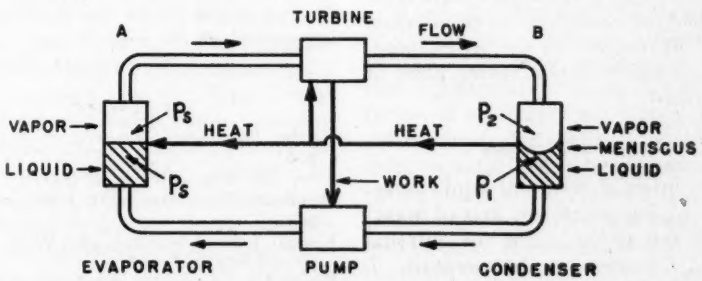

FIG. 1. Diagram of apparatus

In order to maintain the liquid surfaces at a constant level, the rate of flow of liquid through the pump must be equal to the rate of flow of vapor through the turbine, and for a work balance as required by the Second Law

$$ {}_1W_s + {}_sW_2 = 0. $$

Therefore

$$ \frac{RT}{M} \log_e \frac{p_2}{p_s} = - v_s(p_s - p_1). \quad (3) $$

But for pressure equilibrium at a meniscus

$$ p_1 = p_2 + \frac{2S}{r}. \quad \text{(See college physics texts for proof.)} \quad (4) $$

Substitute this value of p_1 into equation (3), which gives

$$ \frac{RT}{M} \log_e \frac{p_2}{p_s} = p_2 v_s - p_s v_s + v_s \frac{2S}{r}. \quad (5) $$

The term $p_2 v_s - p_s v_s$ is very small compared to $v_s 2S/r$ and can be neglected. Equation (5) then becomes the Kelvin equation

$$ \log_e \frac{p_2}{p_s} = \frac{2SMv_s}{rRT} = \frac{2SM}{rRTd_s}. \quad (6) $$

In our cycle we can assume that the rate of flow of the medium approaches zero, and then in the limit equation (6) will give the conditions for equilibrium at the meniscus with neither evaporation nor condensation taking place at that point.

List of Symbols

e_1 = internal energy of liquid entering pump, per unit of mass.
e_s = saturation value of internal energy at temperature T per unit of mass.
p_1 = pressure of liquid under meniscus.
p_2 = pressure of vapor above meniscus.
p_s = pressure of liquid and vapor near flat liquid surface in evaporator. Saturation value corresponding to temp. T.
${}_1Q_s$ = heat flow to pump = 0.
${}_1W_s$ = external work done by pump, work units per unit mass of liquid.
${}_sW_2$ = external work done by turbine, work units per unit mass of vapor.
v_1 = volume of liquid at pressure p_1, per unit mass.
v_s = saturation value of volume of liquid per unit mass, at pressure p_s and temperature T.
v_2' = volume of vapor per unit mass at pressure p_2.
v_s' = saturation value of volume of vapor per unit mass at pressure p_s and temperature T.
S = surface tension, force per unit length.
r = radius of meniscus (+ for convex meniscus, − for concave).
R = universal gas constant.
M = molecular weight of medium.
d_s = saturation density of liquid at temperature T.

I wish to thank Professor Joseph H. Keenan for his suggestion to state that equation (3) in the above proof is required by the Second Law.

WINSTON O. SMITH

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The Fine Arts for Engineers

By HENRY L. SEAVER

Professor in the School of Architecture, Massachusetts Institute of Technology

The teachers of any of the humanities in an engineering school realize perhaps better than do the professional teachers that the American undergraduate is rather more a human being than a technician: None of the humanities is alien from his understanding or interest. Still, our engineering student is an American boy with certain characteristics that have led him into a scientific profession. How can the arts be studied so as to be intelligible and appealing to boys of such a type?

In any group, even of engineers, and fifty years after Victoria, there will be some who before any work of art start upon a personal or sentimental reverie, like Walter Pater contemplating the smile of Mona Lisa, "while the slow mischief spreads from ear to ear." This approach is commoner in girl students; it has sometimes been the approach of a teacher (usually a woman) whom the student had in school courses in art. But prevailingly, engineering students are boys, of the out-door type, the "handy" boy, who deals easier with things than with books or ideas. Fortunately works of art are hand-made things, and the most fruitful approach for many other sorts of students is for the young engineer especially the right and easy one: Considering the object as a craft product—what was it made to do? What difficulties were involved in producing it? What degree of success attained? The professional artist's sensitiveness of perception, as distinguished from his skill of hand, his delicate awareness of pattern, these the engineering student is not likely to share. The subtler skills of design and execution he may not even perceive. But the obvious skills, precision in perception and execution, craftsmanship, in a word, he recognizes with delight and has himself some aptitude for. Two consequences follow: It is desirable (1) without becoming involved in unmanageable complexities, to examine in the classroom various works of art as technical, as craft achievements; and (2) as far as practical, to have the student design and execute some simple but serious work of art.

1. Perception

Which shall be examined more fully, representation or design, picture or pattern? Esoteric modernists insist that representation is an obsolete interest—a distinguished contemporary critic having declared that no serious critic or artist is any longer interested in representation. I doubt if an interest perennial since the mammoth and bison of the cave man has finally perished. At any rate, my experience is overwhelming that all students are—

and intelligently—interested in representation; and that a large and significant part of the art of the world can be presented to them as the solutions, in different ways by different races, schools, or individuals, of the difficulties of representation. To follow the efforts of western painting to attain complete representational truthfulness, and to notice what achievement was possible through elimination of certain effects (as for instance of color) and concentration on others, is a rewarding treatment of painting in a course that must be brief and ignore many very great names. Once aware of the arbitrary exclusions, in his own habit of vision, of this feature or that, the student accepts without difficulty the fastidious selectiveness in the habit of vision of Asiatic art.

I will suggest a few of the problems of representation which the engineering student finds interesting: they are obvious commonplace to the scholar, fresh and amusing to the beginner. Consideration of them gives him a significant general sense of the evolution of Western art, though it does not provide an ordered knowledge of the history of European sculpture and painting.

It interests the beginner to trace the gradual establishment of the convention that a drawing represents the visual experience, not of several and of changing, but of a single, fixed viewpoint. The naiver draughtsman, feeling that the profile is the most recognizable, the characteristic view of leg, arm, and face, and the front view the most characteristic view of trunk and eye, produces the half-plausible compound of Egyptian and some classical art. So also he draws a procession of profile oxen crowned by the magnificent menace of front-view horns. A similar struggle is involved with foreshortening, the truthful drawing of a long object from the short end. These matters, so easily perceived as to need only brief presentation, lead to interesting problems of design. Is the type of drawing and grouping that suggests things going by rather than coming on, of profile rather than of projecting objects, more pleasing in the decoration of a wall? The question merges in a larger: Do we prefer to have all mural design stress flatness, avoiding the recession suggested by perspective, or by wide contrast between its light and dark? Shall we approve a picture only on a scale much smaller than the wall and when limited by a gold frame, yet disapprove, if extended to cover a whole wall? Has the photomural a future? What deferential aloofness, how much reticence do we ask of a wall: Shall its figures say merely "See me go by"; or "Look what's happening here"; "Listen, damn you!" Students will express thoughtfully energetic preference between Puvis de Chavannes and Orozco—tending perhaps to a narrow dogmatism, which had best be met only by the insistence that discussion shall always concern specific examples.

Engineers feel at home in the problem of representing three-dimensional objects on a flat surface; but the consideration of artistic perspective cannot be allowed much time beyond illustrating the primitive conventions for indicating distance, and following the landscape painter's progress, beginning with mere bluing his distances, down through Claude's sensitive "dégradation des lointains."

"Modeling" (in the painter's sense) gets the student promptly into touch with practical matters. For the solid

of simple planes meeting at crisp angles, *e.g.*, a cube, he at once perceives the problem—the determining of "values," the relative light and dark of the three visible sides. For curved surfaces, melting from light into shade, he sees the easier rendering of the modulating brush, and the difficult alternative of hatched lines. Here he is face to face with the printmaker's difficulty of producing tonal effects by breaking or crossing lines. Modelling in two values, one only for all the light and one only for all the shadowed side of an object, can be illustrated from paintings and drawings; and the student feels not only the skill of it, and its effectiveness for representing somewhat distant objects in glaring outdoor light, but also the necessity of it for the simple block print, which must use a single value, the ink, stamped on another single value, the paper.

The painter's progress from the timid flat modeling of the primitives up through Leonardo's rich modelling, to the vivid indication of cast shadow in Caravaggio and after, interests the large proportion of a class who use cameras. They become sensitive to the harsh two-value modeling of a form illuminated by beam or flash light; to the helpfulness of cross-lighting, creating middle values, for a portrait; and at the same time to the expressiveness of cast shadow which reveals surface change not otherwise perceptible. They are always delighted—and taught—by a familiar fine photograph by Ben Ray in which the sensuous contours of a yacht-hull are revealed only by two striping shadows cast by neighboring masts. Photographs of architecture, taken when the cast shadow is more revealing and when less, serve not merely to train observation but also to help the students to more intelligent photographing themselves.

From the simpler illustrations the step is easy to a more perceptive comparison of the handling of light in the great masters of the seventeenth century—the dreamy poetry of light in Rembrandt, the hallucination of El Greco, the silvery sifted mist of Velasquez, the cool daylight of Vermeer which caresses a crinkly map or a plaster wall—all two centuries before it was remarked that "the light is the principal personage in a picture."

Personal experience of the craft problems of sculpture cannot be provided without much time and generous equipment; but class illustration can provide awareness of differences between the carved thing and the modeled thing—the simple, statically monumental contours likely to result from the struggle of chisel with stubborn stone, and the lively surface, a quiver of little digs and strokes and blobs of clay, the shimmer of light and shade likely to result from the tool playing with a gaily responsive material—even when this surface has been duplicated in the hard bronze. Thus starts a right response to the quality of the slate pharaoh with his stony eye fixed on eternity, and the Rodin portrait bronze with its eye not a sightless sphere but a gouged hole in which gathers a pool of shadow like the expressive depth and color of pupil and iris—perhaps even some response to Brancusi's geometries in mahogany or polished brass.

While considering method in representation one becomes inevitably confronted with the matter of selection: Just what aspect of reality is to be represented—surface fact about a motioneless object, or—if some indirection will suggest it—the possibility of

movement? Students find very satisfying the representation of the human figure somewhat generalized, right in the large proportions and the simple massing of the muscles, as in the great Greeks—say Polyclitus and the Spear Bearer; * and as satisfying in modern sculpture—say Rodin's—the accidented surfaces, with much play of small shadow, the flicker of muscle, the quiver of living form. They relate these effects to the two techniques, of carving and modeling. They perceive that, if the aim is to represent power, there is no untruth in the great Moses, though Michelangelo bulges the biceps when the fingers are merely twiddling the whisker. A ship-shape tidiness of habit, to be found not too rarely among engineers, makes them like finished execution, clearness and precision in contours, avoidance of the sketchy: they feel outraged by the ostentatious sloppiness of some modern art. But they accept as convincing, examples of drawing in which, by sacrificing accuracy or completeness of contour, a truth of impression is achieved, the suggestion of motion or power, in place of a truth of scrutiny. They accept very readily the dictum of Ingres, that "drawing is the integrity of art," but will come to recognize the multitude of integrities, the varieties of skill in drawing, the differences between the equally excellent static and dynamic drawing.

A wide field of discussion opens upon considering the representation of ideas, the problem of narrative and symbolic art. Anecdotic pictorial art seems to us today too trivial to give time to: a teacher is tempted merely to share the mirth of a class in beholding that Victorian masterpiece "The Suffering Husband" by the otherwise forgotten Mr. Egg. Many of the students, however, started with Norman Rockwell, just as some of us Victorians started with Rogers' groups; and the problem with the engineering beginner is not to persaude him to dislike the magazine cover but to enable him to find different things interesting. In this field material is available that is not trivial at all, for the greatest art of the world has tried to visualize concepts, especially religious concepts. The Virgin in Christian art is a topic likely to become more philosophic than esthetic; but it can be kept within every student's grasp as a problem in visualizing an ideal. Rather better is the concept of self-sacrifice as the heart of divinity, as visualized in the crucifix or in the Buddhist Kwan-yins and Kwannons. The student recognizes the wide difference between the two problems, that of Christian art with a specific, historical episode in which almost all the details of embodiment are prescribed, that of Buddhist art with a pure abstraction, a divine condescension which must even in its infinite mercy maintain something of its "beautiful disdain."

All these many considerations involved in representation prove perceptible for every student, once pointed out with varied examples; and the perception means, in any but the most inert, the sharpening of observation when fresh examples come to notice. Perhaps the chief gain from a first course in art is this sharpening of the faculty of observation: it is, I am sure, a common one for the engineering student.

Of the many elements that produce esthetic pleasure without any reference

* I find I shun reference to the greatest Greek master since I have twice in students' papers faced his name in this cruel spelling: Phideous.

to representation, color is the most difficult to handle with classes, partly because there are but few, and expensive, colored slides and prints; partly because training the eye to exact color response is a slow, almost professional business. Students thrill to a fine color-wheel, and get the obvious notions of complementary or adjacent color schemes; but this is a barren perception. Not too much time is needed to illustrate a principle or two of design: *e.g.*, that a pattern with small difference between its values, its light and dark, admits a wide variety of colors, and one with a wide difference becomes garish if more than a pair of colors appear. Such ideas can best be illustrated from textile design or ceramics; there is the advantage that actual textiles may be shown; but there is the disadvantage that the engineer harbors a suspicion that this is all mere dressmaker's business. His interest in the representational part of painting sustains an interest in the painter's use of color. A few prints will show him the preference of the "old" masters for pure colors at maximum intensity, and the turning of the later Renaissance painters to modified colors, red glowing toward orange or sobering toward purple, the preference for reduced chroma, for tints and shades. The student can be brought promptly to note that a given picture is an "arrangement" in blue and coral, or a modulation in browns, or a wallow in all the yellows; that color has been dictated by concern for representational truth or altered in the interest of color pattern.

For consideration of mass, area, and line, architecture, the art of kings, supplies royal examples. The material is abundant but, I think, difficult. Perhaps because of my own unresourcefulness, I have achieved no effective condensation or simplification of architectural material for class uses. One topic goes well: The non-representational decoration of a wall. Few, even among engineers, who find this a congenial topic, are so "functional" as to accept construction as the complete answer; they approve surfacing; even see no "insincerity" in veneers; will compare judicially the medieval wainscot of little panels such as a carpenter makes in constructing a chest, with the architect's lay-out in pediments and pilasters, and with the modern preference for plane area and dislike of mouldings. He is provoked to reflection by the asymmetrical marshaling of rectangles in a wall design by Mondriaan, and is not recklessly ready—though engineers are all for symmetries—with an answer to the question: Under what conditions do we accept departure from architecture's preference for lateral symmetry?

A compact topic in pure pattern, manageable even within a class hour, is the grill or lattice. Delightful examples may be gathered from metal work, from the rich variety of Chinese window lattices, and from the Japanese sword-guard. Engineering students have something of the carpenter and the smith in them, often some training in these crafts, and are ready with response to the design problem—in which a constant element is to choose between pure non-representational pattern and the admission of some representation, subject to conventionalizing.

Most rewarding, in the field of purely non-representational pattern, is consideration of type design—the more important for its ubiquity and the current obtuseness to artistic quality in printing. A bit of history and an abundance of illustration enable stu-

dents to acquire a feeling for the character of type faces, to discriminate between the robust and the delicate, then between a vital and a fragile delicacy. It is essential to pass about in class the best examples of great printing: the pitying glance at the lovely captive in a showcase is quite different from caressing the cover and turning the page of a sumptuous book in your hand. A Bodoni folio, the Kelmscott Chaucer, the Doves Bible, the Ashendene Dante let loose in a class room mark an event in the humdrum of teaching. Equally appealing is the esthetic of book illustration, more particularly that which accepts Morris's principle that the illustrative material is to be congruently related to type character. The crisp preciseness, the metallic perfection of letterpress, the "decency of the definite" (Henry James's phrase) delight the engineer's mind, and he resents setting amid or opposite these, in an illustration, a contourless smear of indecision.

The pattern interest in representational art is much discussed in manuals, and many students, especially the camera enthusiasts, are champions, or victims, of somewhat dogmatic theories of "composition." I am myself sceptical of most of them, and restive under all. I know, however, that the undergraduate is interested in certain large considerations of constructing a picture—*e.g.*, Wölflin's points about the linear and the "painterly," about the plane and the recessional grouping of the figures. He is quick to see the monumental symmetries of the Renaissance picture as contrasted with the pungent casualness of Degas; he will write a good paragraph on painting a wall in the manner of Degas; but I rarely persuade engineers that there is anything delightful in the martialed splendors of the grand-manner landscape of Claude or Turner—they are all for charm and "bits." It is rewarding to note how, in a narrative painting, the story requirements and the decorative have to be reconciled, preferably in an example from religious art, *e.g.*, the Last Supper: How artists wavered between presenting the prediction of the betrayal, or the communion—finding both together confusing; how unmanageably awkward is John "lying in his Lord's bosom"; how difficult, yet in the end solvable by a device of composition, to identify Judas among twelve disciples who have no generally recognized symbols.

2. Practice

Any course in the Fine Arts, as a measure of the student's perception in all the matters presented in class, will require frequent written comment on museum exhibits, on selected exhibits arranged in the school, on public monuments. There is in such reports the element of production inherent in all writing; but it is criticism, not creation. All critics profit by the attempt, at least, to create; and though among engineers aptitude for representational drawing is not common, they should be encouraged—perhaps in the desperate case not required—to produce something. In half a hundred there will be a few with distinct aptitude, not impossibly in painting or modeling, which they should be encouraged to exercise and have criticized. In one field I have found almost universal willingness to try: the graphic arts. The relief print from a linoleum block involves the least in equipment and in skill of hand; and it is no disadvantage that many students have already in school made a first try. Class presentation of fine examples from old and from contemporary block print masters usually stirs a bit of

emulation. The self distrustful can be encouraged by examples of pleasing prints in pure silhouette—such as a simple dogwood spray that printed white on a black ground, which a diffident Chinese student once did for me. The encouraged beginner is not likely to do as well—unless he has bred in the bone an ancestral Asiatic instinct for pattern; but he will have made the effort, which is profitable even when without success.

What, in the end, may a course in the Fine Arts hope to accomplish for engineers? Some simple, definite things: Intelligent acquaintance with the collections in local museums, very rich in Greater Boston; and better, an intelligent habit of visiting a museum with willingness to look only at limited, related matter at one visit. Then, the awareness that matter of artistic interest far exceeds museum collections. Then, the larger habit of noticing and a sharper faculty of observation, even the beginning of critical faculty—at least the experience that some works are briefly and others more permanently pleasurable. Supremely, the widened range of enjoyment, the enlargement—for some, the beginning—of the most serene of the "durable satisfactions of life."

One vice sometimes initiated by a course in art the engineering student is little addicted to, the pretense of liking something because it is considered "cultivated" to. At the beginning of the course I promise passing rank to any student who does not loaf and who preserves the admirable sincerity of a Harvard undergraduate, the hero of a true story reported by President Lowell: This student, obtaining a low grade in a Fine Arts course, was admonished that he seemed inert, never asked questions. At its next meeting the class was shown a Siennese primitive, an ethereal, etiolated Virgin, painted very flat on a gold background of eternity, a thing of exquisite but very special charm, which our student did not feel in the least. They were told merely that it was a Siennese altar panel, of the Madonna and Child. The boy lingered after class, to enquire of his professor: "Is the child a boy or a girl?" *

* I regret to add as a footnote that this story has once or twice lately misfired, in my class, several students smiling vaguely and saying: "Which was it?"

Mathematics and Electrical Engineering

By G. F. CORCORAN

Professor and Head, Dept. of Electrical Engineering, University of Maryland

The advantages to be gained by stricter correlation between courses in mathematics and those in electrical engineering are well understood. The beneficial effects of this type of correlation can be observed in the second semester of the sophomore year in schools that teach a *fundamentals* course concurrently with integral calculus, provided the *fundamentals* course is taught on a basis which will require the student to use the calculus.

While it is true that most of the subject matter in a *fundamentals* course can be taught without the aid of the calculus, it is equally true that the subject matter can be covered much more adequately by proper applications of the calculus. Where the subject matter concerns the calculation of:

- the resistance of conductors of various shapes,
- the capacitance of one conductor relative to another,
- the self-inductance of different circuit configurations,
- the effective and time-averaged values of current and voltage,
- the forces on charged particles in electric and magnetic fields,

it is usually advisable to explain the physical significance of these calculations with examples involving only algebraic manipulations. These examples can be followed by others (usually of a more practical nature) which require calculus solutions. Then finally an example or two can be given which involve geometries (or functions) which can be handled only by graphical or trial and success methods. This procedure serves to emphasize the advantages of analytical methods.

The teacher of electrical engineering fundamentals who confines his instruction to those cases which can be handled algebraically is not only restricting the subject matter unnecessarily, but he is depriving the student of the opportunity to practice the mathematical techniques learned in any standard calculus course.

At the sophomore level, the correlation in question can best be accomplished by careful teaching of the electrical course since the student will ultimately benefit more from a well-rounded or standard calculus course than from one which devotes too much time to elementary applications.

At the junior level, a more integrated plan can be inaugurated in schools that teach *differential equations* or *applied calculus* concurrently with a second course in *electrical engineering fundamentals,* sometimes called *electricity and magnetism.* Coordination is required both on the part of the mathematics professor and on the part of the electrical engineering professor. Mathematics courses for junior electricals only are also required

but this presents no serious problem since the increased enrollments in most engineering colleges justify the division of students by departments. The subject matter in the electrical course must be correlated not only with the junior mathematics course but also with the other required electrical courses. At the University of Maryland, "Differential Equations" (Math. 64) is the last required course in mathematics for electrical engineers so correlation at the undergraduate level must be accomplished here if it is to be accomplished at all. The relationship of the two courses in question (Math. 64 and E.E. 60) to the remaining electrical engineering courses is shown in tabular form below.

	Sem. Hrs.	Textbook
Junior Year (First Semester)		
Math. 64 Differential Equations	3	Reddick and Miller
E.E. 60 E.E. Fundamentals II	4	Transients, Kurtz and Corcoran Duplicated Notes
E.E. 100 A-C Circuits	6	Kerchner and Corcoran
Junior Year (Second Semester)		
E.E. 65 D-C Machinery	4	Kloeffler, Brenneman, Kerchner
E.E. 101 Engineering Electronics	6	Reich's Large Book
E.E. 104 Communication Networks	3	Ware and Reed
Senior Year (Both Semesters)		
E.E. 102–3 A-C Machinery	8	Puchstein and Lloyd
E.E. 105–6 Radio Engineering	8	Terman
E.E. 109–114 U.H.F. and Applied Electronics	6	Brainerd-Reich

In spite of the imperfections in the required courses and in the textbooks used, the fact remains that some success in correlation is possible if suitable topics of study are selected in the Math. 64 course and in the E.E. 60 course. Concurrent and correlated teaching of linear differential equations in Reddick and Miller with the "Transients" portion of E.E. 60 for one-half semester will provide the student with a 3.5 semester-hour course in elementary transients or natural circuit behavior. The second half of the semester can then be devoted to specialized topics agreed upon by the two professors involved. The precise nature of the specialized topics will obviously depend upon the textbooks employed in the subsequent electrical courses. For the textbooks used at the University of Maryland, the specialized topics which have been found to be most useful are:

1. Applications of the Cauchy-Riemann Differential Equations (Curvilinear-square field mapping).
2. Applications of Laplace's and Poisson's Equations (Derivation of Child's Law for example).
3. Taylor's Series Expansion in Two Variables (Plate current expansions in e_g and e_p).
4. Solution of a Bessel's Equation in Terms of ber and bei Functions (Derivation of effective resistance in cylindrical wires).
5. Fourier Series in Complex Form and Fourier Integrals (Frequency spectrum analysis).
6. Derivation of Maxwell's Equations from Line Integral Forms (Simple applications).

Hyperbolic functions and long-line theory are not included in the specialized topics because they are covered quite adequately in Ware and Reed, E.E. 104, which is taught the second semester of the junior year.

With Math. 64 and E.E. 60 properly correlated, the student obtains the equivalent of 3.5 semester hours instruction on the specialized topics listed above. During the course of this instruction it is hoped that he will acquire some fundamental and useful knowledge of electricity and at the same time learn some mathematical techniques which will be of lasting benefit to him.

	Sem. Hrs.	Textbooks or Notes
First Semester Courses		
Operational Calculus (Math.)	3	Churchill
Operational Circuit Analysis (E.E.)	3	Gardner and Barnes
Automatic Regulation (Servos) (E.E.)	3	Mr. Ahrendt's Notes, using Laplace Transforms and Frequency Spectrum Analysis
Second Semester Courses		
Vector Analysis (Math.)	3	Phillips
Radio Wave Propagation (E.E.)	3	Mr. Katzin's Notes and Research
Advanced Radio Engineering (E.E.)	3	Mr. Davies' Notes and Ramo and Whinnery

Correlation of the type under discussion is again possible at the graduate level. One method which has been put into practice by the electrical engineering department at the University of Maryland is to employ a professional mathematician on its staff. Experience has shown that the professional mathematician with some interest in the physical universe can teach some graduate courses in electrical engineering in a highly successful manner. (The writer firmly believes that an electrical engineering department which offers a well-rounded graduate program can well afford to have one or more professional mathematicians on its staff.) The mathematician with suitable interests and background is well qualified to teach courses in advanced circuit analysis and the theory of servo-mechanisms. He is also qualified to carry on research work in these fields and to direct student research work.

Normally, the graduate student in electrical engineering is required to take from six to nine semester hours of formal mathematics (as taught by the mathematics department) as a partial requirement for the Master's degree. (The Doctor's degree is not as yet being undertaken by the electrical engineering department at the University of Maryland.) Two examples of correlation at the first-year graduate level are shown below:

A good example of strict correlation between a mathematics course and a course in electricity was revealed to the writer recently by Dr. L. W. Ball, Chief of the Mechanical Test Division, at the Naval Ordnance Laboratory. At Manchester University (in England) where Dr. Ball studied "Electricity" under Professor Bragg, the vector and tensor analysis required was interlaced very carefully with the electricity course. Techniques in vector and tensor analysis learned one week in the mathematics course (taught by Professor Hartree) would be followed (in a very few weeks and in some cases the very next week) by applications in the electricity course requiring these same techniques. After some more experimenting with correlation between junior courses at the University of Maryland, we hope to improve the correlation at the graduate level along the lines adopted at Manchester University.

Comparison of Industrial Engineering Curricula

By JAMES M. APPLE

Associate Professor of Mechanical Engineering, Michigan State College

In working on the development of an Industrial Engineering program at the Michigan State College, I naturally began to wonder—"What subjects do the other schools offer in this curriculum?"

This survey is an answer. The accompanying chart is based on a list of accredited curricula issued by the E.C.P.D. It includes colleges offering four year courses in industrial, management, or administrative engineering, as well as those offering an industrial engineering option under mechanical or general engineering.

The analysis was based on the material contained in catalogues issued by the colleges. It should be noted, however, that several factors made an exact comparison of curricula next to impossible. Some of these factors are:

1. Variations in course titles.
2. Vague course descriptions.
3. Incongruity between titles and descriptions.
4. Variations in methods of listing course credits.
5. Combining different subject matters into one course.

The analysis was made with the objective of determining those courses offered which caused the industrial engineering curricula to differ from basic mechanical engineering. For that reason, only courses which can be classified as industrial engineering are tabulated, and some borderline cases are omitted, such as economics, psychology, machine design, shop courses, etc.

It should also be pointed out that electives, or other courses offered by the Industrial Engineering Dept., but not listed in the curricula, are not considered. The chart is an attempt to *compare* industrial engineering *curricula* as presented in the catalogues.

Also, the credits indicated are only approximate due to the various methods of determining credits, *i.e.*, terms, quarters, semesters and miscellaneous methods of calculation. Also, in some cases, where the course seemed to cover two subjects, the credits were divided between them.

However, it is possible to draw some conclusions from the data as tabulated.

I. *Courses offered by 50 per cent or more of the 25 colleges.*

1. Motion and Time Study.
2. Industrial Management.
3. Accounting.
4. Industrial Organization.
5. Personnel Management.
6. Cost Analysis and Control.
7. Engineering Economy.

II. *Courses offered in order of popularity.*

Course	No. of Schools
1. Motion and Time Study	21
2. Industrial Management	18

Course	No. of Schools
3. Accounting	17
4. Industrial Organization	16
5. Personnel Management	14
6. Cost Analysis and Control	14
7. Engineering Economy	13
8. Plant Layout	12
9. Production Control	12
10. Engineering Law	9
11. Marketing	8
12. Management Seminar	7
13. Statistics	7
14. Financial Management	7
15. Tool Engineering	6
16. Safety Engineering	6
17. Materials Handling	5
18. Inspection Trip	5
19. Job Evaluation	4
20. Industrial Surveys	3
21. Quality Control	2
22. Industrial History	2
23. Graphical Presentation	2
24. Budgeting	2

III. *The approximate number of credits allotted to all Industrial Engineering subjects is 28.4 in four year curricula.*

So there it is! Where does your school stand?

Note: Due to the difficulties of making an accurate presentation, some schools or courses may have been somewhat misrepresented. The author will appreciate constructive comments from the schools included or those which may have been omitted. It is possible that a more exact comparison may be made in the future. In fact, it might be wise to hold a meeting of those persons interested in "standardizing" or just discussing industrial engineering curricula.

J. M. A.

COMPARISON OF 4-YEAR INDUSTRIAL ENGINEERING CURRICULA

Notes:
1. Only 4-year courses are tabulated.
2. Industrial, Management, and Administrative Eng'g. are included.
3. In some cases, credits are approximate.
4. Electives are not included.

	Alabama Poly. Inst.	Alabama, Univ. of	California, Univ. of	Carnegie Inst. of Tech.	Columbia Univ.	Florida, Univ. of	Georgia Sch. of Tech.	Illinois Inst. of Tech.	Lafayette College	Lehigh Univ.	Mass. Inst. of Tech.	New York Univ.	Ohio State Univ.	Oklahoma A. and M.	Penna. State Coll.	Pittsburgh, Univ. of	Rensselaer Poly. Inst.	Syracuse Univ.	Virginia Poly. Inst.	Options under Mech. or Gen'l. Eng'g.								Number of schools offering the course
																				Akron, Univ. of	Iowa State Coll.	Mich. State Coll.	Purdue Univ.	Santa Clara, U. of	Washington, U. of			
Accounting—general	3⅓		6	5	3	4		3	3	3	3	2	3⅓		2	6	3		3	3								17
Budgeting	3⅓																		3									2
Cost Analysis and Control—pricing, cost accounting, estimating	3⅓				2		2	3	3	3		2	3⅓		4		6		3				3	7	3			14
Engineering Economics—finance, valuation, industrial econ., equip. selection, investment	6⅔	3	3		2	3	3			6		3		3	3			3	8			6						13
Engineering Law—business law, jurisprudence, contracts and specifications		3				1⅓		3	3	3	3		2			2						3						9
Graphical Presentation												1										3						2
Industrial History—industrial development			1									2																2
Industrial Management—laws of management, scientific management	3⅓			6	1⅓		1⅓	3	3	3	1⅓	4	2	3	2	2	3		6	3	3		3					18
Industrial Organization—principles of organization, department functions		5	3	7	1⅓		1⅓		1⅓		1⅓	2	2⅔	3	6		3	2			5	4		1				16
Industrial Surveys—reports, case studies, production problems							5				3									3								3
Inspection Trips—factory visits		0			3								2⅔					1	0									5
Job Evaluation						2															4	2		1				4

COMPARISON OF 4-YEAR INDUSTRIAL ENGINEERING CURRICULA—*Continued*

Notes:
1. Only 4-year courses are tabulated.
2. Industrial, Management, and Administrative Eng'g. are included.
3. In some cases, credits are approximate.
4. Electives are not included.

	Alabama Poly. Inst.	Alabama, Univ. of	California, Univ. of	Carnegie Inst. of Tech.	Columbia Univ.	Florida, Univ. of	Georgia Sch. of Tech.	Illinois Inst. of Tech.	Lafayette College	Lehigh Univ.	Mass. Inst. of Tech.	New York Univ.	Ohio State Univ.	Oklahoma A. and M.	Penna. State Coll.	Pittsburgh, Univ. of	Rensselaer Poly. Inst.	Syracuse Univ.	Virginia Poly. Inst.	Options under Mech. or Gen'l. Eng'g.						Number of schools offering the course
																				Akron, Univ. of	Iowa State Coll.	Mich. State Coll.	Purdue Univ.	Santa Clara, U. of	Washington, U. of	
Marketing—sales eng'g., merchandising, sales organization, sales mgmt.				3				3			4	2				3	3	3			3					8
Materials Handling—transportation, traffic mgmt.	3⅓						3									3	3					1				5
Motion and Time Study	3⅓	8	3	3	3	3	5	2				4	6⅔	2	3	5		5	3	4	5	2	3	3	3	21
Personnel Management—industrial relations, labor mgmt., human eng'g.	3⅓			3	2	2		3		3	3	2		3	3	3				3	6		3			14
Plant Layout—factory planning, manufacturing planning	3⅓	5	2		3	4	3		3			3		3	2						5	1				12
Production Control—production planning, production organization	3⅓	5	3				3		1½				10			6			3		5	2	3		3	12
Quality Control—inspection	3⅓																								3	2
Safety Engineering—industrial safety	2	3				1½					3	2	2	1		3					3					6
Seminar—management, S.A.M.				6							3	1		1		2	6						3			7
Statistics					3			3																4		7
Tool Engineering—jigs, tools, fixtures, dies, gages			3							1		2		2	3								3			6
Financial Management—financial org'n., industrial finance	3⅓							3	6	3	3	2					6									7
Credit Totals	45⅓	33	23	33	24	21	27	26	24	25	28	34	36⅔	21	28	35	33	14	29	16	51	12	24	16	12	

Professional Vices of Teachers of Science and Engineering*

By B. B. BENNETT

Head, Dept. of Languages, Michigan College of Mining and Technology

Any analysis of the professional vices of teachers of science and engineering in the American educational system must be made against the background of an historical fact. It was not until fifty or sixty years ago that the sciences—mathematics, the "discipline science," excepted—were regarded as fit material for educational institutions. The so-called classics dominated the educational program, and the sciences were considered toil for the inveterate tinkerer. The technological developments of the last two decades of the Nineteenth Century, however, made America conscious of the fact that science was affecting the customs and habits of the people.

Encouraged by the receptive attitude on the part of the public, science put a tentative foot in education's door; the classics, practicing their preachments of tolerance, permitted the door to be opened wide. Science moved in and took over the place. Perhaps because of the questionable respectability of the background of science the new-found acceptance into legitimate circles went to the heads of the teachers of science. In any event, science teachers acquired an attitude which they have not yet thrown off: a consummate arrogance.

This arrogance appears to stem from the conviction that science is the only pursuit worth the time and effort of students, that most other fields of study are somewhat sissified folderol, and that only the effete and the dilettante squander their mean energies in the humanities. In addition to the recently recognized legitimacy of scientific education, there were other reasons for the arrogance. Millions of dollars were spent by the colleges and universities of the country for new buildings and for equipment with which to fill them; big universities vied with each other to get the "best" men, and salaries consequently zoomed; students who wanted to "learn to make a living" flocked to the "best-equipped" institutions.

The arrogance of the teacher of science and the emphasis on his newly achieved prestige led to the trend towards segregation. Each branch of science began to feel "most important" in the educational process, and there was a marked tendency for each branch to isolate itself from the others. As a result there were interdepartmental struggles, secret alliances between some departments, and subversive attacks against other departments. The evi-

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dent consequence of this movement toward segregation was disintegration—diametrically opposed, of course, to one of the major objectives of education: integration. In some universities each of the science departments became virtually a separate college. There were, in effect, colleges of chemistry, of physics, of geology, and even of paleontology, each intent upon monopolizing the time of the students. It is not too difficult to imagine this process carried to the reductio ad absurdum—a college of quantitative analysis, for example, competing with a college of qualitative analysis.

The feverish attempt to absorb more and more time of more and more students led to one of the most virulent diseases of our educational system: Laboratoriosis. It is appalling to think of the number of hours that college students spend in the performance of repetitive mechanical manipulation. Of course, that is all right if our aim is to produce animate robots. But is it?

The obvious protest here is that "we learn by doing." To any serious thinking educator, that old saw is wholly unacceptable. If we accept it we deny the whole purpose of the educational process. Animals, it is true, learn by doing; but the degree of our rise above the animal level might well be measured in terms of what we can "learn without doing." Had I more time I would be happy to develop this thesis; but it is at the moment a tangent. My major point is that teachers of science worship at the shrine of Paraphernalia. Indeed, science departments are often judged on the quantity and variety of the gleaming gadgets they display. Also, science departments—in undergraduate institutions, mind you—are judged on the research they "produce." Which brings us to an additional evil.

Researchitis is another disease which has undermined the health of science teaching. For some inexplicable reason the science teacher who hopes to rise above a substandard of living must have a Ph.D.—regardless, of course, of his ability to teach. It is widely admitted that having a Ph.D. is very much like having one's teeth straightened—it makes one more professionally or socially acceptable, depending upon one's aims. To procure the Ph.D. the science teacher must necessarily submerge himself in research; and the submersion process starts a chain reaction which is not easily stopped. Research becomes the sole standard of evaluation and thus the major goal for all teachers of science. That means less teaching, if any, to narrower groups, if any. For example, the fact that Dr. Fermi, of atomic fission fame, actually taught a class at the University of Chicago was startling enough to receive publicity in most of our metropolitan newspapers.

The major after-effect of Researchitis is the relegation of actual teaching to the underpaid instructors who either cannot afford to have their teeth straightened (and may possibly be good teachers) or are too dull to want to have their teeth straightened (and probably aren't good teachers).

A variant manifestation of Researchitis is Administrationism. Science teachers constantly strive for administrative positions wherein they will do little or no actual teaching. While this habit is general in the educational system, the teachers of science appear to be the most confirmed addicts.

My final criticism of teachers of science and engineering may surprise you somewhat. Indeed, you may already

be surprised that I have not excoriated the teachers of science because they know so little about the so-called humanities. That is such an obvious criticism that I choose to ignore it. I cannot, however, ignore the fact that students who graduate with a B.S. degree —and, I might add, a majority of their teachers—are so woefully lacking in their knowledge *about* science.

Now, I admit that they know a lot of science; but I believe that it is an acceptable fact that they do not know much *about* science. Science, or one phase of it, they may know thoroughly as an isolated unit; but they have no understanding of the part's relationship to the whole. To draw a comparison from the field of mechanics, a man may be a carburetor specialist and still have no conception of the relationship of the carburetor to the function of the machine of which it is a part. In other words, he knows nothing *about* carburetors.

This narrowness in the man skilled in science manipulation does not permit him to have a set of values adaptable to the social and economic system in which people must live. And if one lacks a practicable set of values one has very little that can be accurately called education. Furthermore, one is not competent to apply his scientific knowledge to the vast complexities of human relations. For example, eight out of ten men trained in science, if asked to name the two greatest scientific events of all time, would give answers such as the invention of the wheel, gunpowder, the steam engine, electricity, or atomic energy. The correct answers, of course, are the promulgation of the Copernican theory and the formulation of the Darwinian theory. Beside those two things the others are relatively insignificant.

In conclusion, I should like to remind you that the assigned purpose of this paper was to stimulate discussion and self-examination. In attempting to fulfill the assignment, I may have overstated the case. But it is quite likely that on some of the needles I have stuck into some of you there is enough of the caustic of truth to sting a little.

The Physics Laboratory in an Engineering School

One Solution to the Problem of Assigning Grades to the Student in the Sophomore Physics Laboratory

By C. J. PRATT

Assistant Professor of Physics, Michigan College of M. and T.

The Physics Staff of the Michigan College of Mining and Technology has been very busy during the past two years working on the problem of "what to do about the Sophomore Physics Laboratory" with reference to course content and the assignment of grades to students taking the course.

Historically, grades received for the work in the Laboratory were somewhat higher than those earned by the same students in their class work. As a result the "Laboratory" was often looked upon as a source of "gravy" to help the student through the general physics course.

The first definite step toward solving this phase of the problem was the complete separation of Class and Laboratory with the provision that the student must pass each on his performance in each. Failing one did not necessitate retaking the other. Class and Laboratory for the same division of Physics had to be taken concurrently.

The Michigan Tech. year is divided into four twelve-week terms and the Physics course is broken into three terms' work: Mechanics and Sound, known as B-1; Heat and Light, known as B-2; and Electricity and Magnetism, known as B-3.

The separation of Class and Laboratory did not necessarily mean that the distribution of grades in the Laboratory work would be normal as evidenced by the data shown below:

B-1 Lab. Final Grades	Number of Students	High	Low	Q_1	Q_2	Q_3	Q
Summer, 1945	14	94	77	83.0	86.8	89.7	3.35
Fall, 1945	40	94	60	83.3	86.4	89.5	3.10
Winter, 1946	23	91	65	78.4	82.3	88.4	5.00
Theoretical Values				76.5	81.7	86.8	5.15

In which Q_1 is the lower quartile, Q_2 the median, and Q_3 the upper quartile deviation, and $Q = \frac{1}{2}(Q_3 - Q_1)$.

The grades given in the three terms listed above were based upon personal observation of the student in the Laboratory and the nature of the report submitted by the student. In the summer and winter terms there was one section and in the Fall there were three sections, each under a different instructor.

The close agreement between the

grades assigned during the Winter term and the theoretical values is the result of a definite attempt to solve the problem of the assignment of marks. At this time it became apparent that it would be necessary to devise a system whereby like results could be obtained for larger groups, supervised by several different instructors.

The first step in the setting up of a testing program was listing the aims to be fulfilled; this was followed by a study of what could be done to carry out the program, and by the building of Mid-Term and Term-End Examinations based on a sampling of the topics taken up during the term.

The data shown in the following table are based upon the results of the testing program in the Spring and Summer terms of 1946. The grade was based equally on the examination scores and the report marks assigned by the instructor.

B-1 Lab. Final Grades	Number of Students	High	Low	Q_1	Q_2	Q_3	Q
Spring, 1946	35	93	65	77.3	82.5	85.8	4.25
Summer, 1946	48	93	65	74.8	81.8	86.4	5.80
Theoretical Values				76.5	81.7	86.8	5.15

The results of the Spring and Summer terms rather closely parallel those of the Winter term of the same year with an increasing load and more sections. The distribution of grades did not depart from the theoretical values to a greater degree than that to be expected when dealing with small groups. However, another factor entered at this point to complicate the problem.

It was found that the Mid-Term and Final Examinations revealed that large sections of the whole group had failed to grasp the full significance of a part of the work covered during the period over which the test extended, but by the time the information came to the instructor's attention it was too late to do any remedial teaching over these items.

To remedy this situation the B-1 Laboratory was reorganized into five Units of work, each of two weeks duration, with a completion type test given at the end of each Unit. In this way it was possible to test a student's progress over that part of the work and to correct errors and omissions while the topic was still fresh in his mind.

The topics covered in the separate Units were:

Unit I—Vector Operations, Measurement of Distances and Areas, and the Determination of Probable Error.

Unit II—Free Fall, Free Body Diagrams, and Friction.

Unit III—Newton's Second Law of Motion and Static Equilibrium (Coplanar Forces).

Unit IV—Work, Power, and Efficiency, Simple Machines, and Young's Modulus for Stretching.

Unit V—Vibrating Strings and Speed of Sound by Resonance.

The student spends the first four-hour period and the first three and one-half hours of the second period of each Unit doing the experimental work, on which he writes a report during the

time he is in the Laboratory. During the last half hour of the second period he is given a Unit Quiz covering the major items in the experimental work.

At the end of the term he is given a comprehensive examination over the work covered during this period.

The student's term grade is based upon scores earned from Laboratory Reports, Unit Quizzes, and the Final Examination, each part having the value indicated below:

Laboratory Reports	25%
Quiz Scores	25%
Final Examination	50%

The student's Mid-Term grade is based upon the sum of the scores earned for the first two Units of work, giving the Laboratory Reports and the Quiz Scores equal weight.

The results of the testing program for the Fall Term of 1946 are shown in the table below:

B-1 Lab. Final Grades	Number of Students	High	Low	Q_1	Q_2	Q_3	Q
Fall, 1946	225	97	50	77.7	83.5	87.8	5.00
Theoretical Values				76.5	81.7	86.8	5.15

In the Fall term of 1946 the 225 students were divided into 14 sections under eight members of the Staff. To simplify the scoring system the method shown below was used.

Item	Points for Each Unit	Total
Experiment Report	16	80
Unit Quiz	16	80
Final Exam.	—	160
Final Score		320

The final scores showed a spread from 113 to 289 out of a possible 320 points. This greatly simplified the actual process of determining a grade at the end of the term and left no doubt in the minds of the instructors as to the relative standings of the students taking the course.

While this system has been set up in its present form for both B-1 and B-3, results are not yet available in the latter course. The system is being extended to B-2 Laboratory with every expectation that the determination of a fair grade in Sophomore Physics Laboratory is not an impossible, or even a difficult achievement.

A Practical Teaching Credo

By A. D. TOPPING

Missouri School of Mines and Metallurgy

It may be said that there is no such thing as teaching—there is only learning. The role of the student must be an active, not a passive one. The task of a "teacher" is to bring to the attention of the student things which it is desirable that the student should learn, as he might lead a horse to water; but he can't make him learn. One may try to help a pupil learn, but efforts in this direction will consist principally of pushing him closer to the water. The gauging of the progress of the student through the medium of tests and reporting on it through the medium of grades is, of course, a minor responsibility of the "teacher" which has, however, attained considerable importance under the present system of higher education.

If the relatively passive part of the teacher in the process of education is not fully realized by him, poor teaching will result: he will almost inevitably work himself into the position of lecturer. Of lecturing, Abbott Lawrence Lowell said, "The time has passed when instruction can be given purely by lectures—as the Moors after the conquest of Granada were baptized by sprinkling in crowds." And, more specifically, Thomas DeQuincey wrote, "College lectures, whether public or private, are surely the very worst modes of acquiring any sort of accurate knowledge, and are just as much inferior to a good book on the subject as that book hastily read aloud, and then immediately withdrawn, would be inferior to the same book left in your possession, and open at any hour to be consulted, retraced, collated, and in the fullest sense studied." The comparison would be difficult to improve upon.

But suppose there is no good book on the subject? Then use a poor one—that is better than nothing; or write one. I will venture to say that no teacher ever found a textbook completely satisfactory which he did not himself write, and perhaps not even then. Not every one can get a textbook published at will, of course; besides which, a great deal of time and effort is involved in the preparing of a book for publication. But why not take that set of notes which you have been reading or writing on the blackboard or reciting from memory in your classroom to the department secretary and have mimeographed copies run off for your students, instead of allowing them to scribble what their hasty and inexperienced judgment leads them to believe is important? Your valuable class time can thus be made available for matters of greater moment than the merely clerical work of transcription.

Lecture courses in which students take notes to be studied in lieu of a text, or in addition to one, are wasteful of the students' time. One suspects

the reason for the prevalence of this method of conducting a course is a lack of ability to use the available time in any other way. With engineering curricula so crowded with necessary basic instruction together with desirable new courses needed to keep abreast of engineering developments in industry, such practice seems reprehensible.

If the students are learning all that they need to learn in classes consisting of lectures, the number of weekly meetings could be reduced if a text were used and the time given over to some other course. But assuming that the students are *not* (and I imagine few teachers are entirely satisfied with the progress of their proteges), how should the time be used? That wise old Frenchman of the sixteenth century, Montaigne, had some constructive suggestions (as well as a caustic comment on the lecture system): "The usual way is to keep bawling into the pupil's ears as one pours water into a funnel, the pupil's business being merely to repeat what he has been told. . . . Let the tutor demand of him an account not only of the words of his lesson, but of their meaning and substance. . . . Let him show what he has just learned from a hundred points of view, and adapt it to as many different subjects, to see if he has yet rightly taken it in and made it his own."

Application of this to twentieth century engineering schools, to my mind, means plenty of quizzes, not too easy. Quiz problems exactly like those worked out in class or in the book except for the numerical values would plainly be anathema to Montaigne. The plaint of the student who has "never had one like that" must be ignored for his own good. In fact, good quiz problems should for the most part be as different from those previously considered as it is possible to make them and still employ the same principles. To take an elementary example, the student who has learned how to find the resultant of two forces should also know, given the resultant and one of the forces, how to find the other force; else he has not "yet rightly taken it in and made it his own."

Since the use of many class meetings for hour quizzes is not ideal, quite aside from the burden of paper grading which would result, the desirability of frequent quizzes has given rise to the "ten minute quiz" (or "shotgun," as it has become known on the campus of the Missouri School of Mines), given either unannounced or at every meeting. The latter is preferable where heavy schedules do not make the teaching load excessive. The quizzes should be given at the beginning of the hour so that they can be explained immediately, and should be corrected and handed back by the next meeting so that the student may profit by his mistakes. To give the quiz at the end of the hour, on the subject which has just been discussed, is poor both practically and theoretically; given at the start of the period, the "shotgun" provides an incentive for the student to get to class on time and makes it unnecessary for the instructor to have to pull papers out from under the everpresent laggard's pencil in order to get away to the next class. More important, an incentive is given the student to do his homework; knowing that all will be explained on the morrow before he will have to demonstrate his knowledge makes it easy for the student to decide to spend his study time on something else, or to give up at the first difficulty met with in the assignment. Too, giving the quiz at the start permits the teacher to show the student his error, and correct it, while

the problem is still fresh in the student's mind and a matter of interest to him; next day the problem will often have staled.

The great virtue of the ten minute quiz (which, incidentally, may last considerably longer than ten minutes on occasion) is that it enables the student to learn by doing; to find out what he has missed in his studying. A man can read an article on a subject and believe that he understands it, and then, on attempting to solve a problem, find that he doesn't even know where to begin. The teacher may work out problems on the board until his arm aches, but until the student himself works some, he has not "yet rightly taken it in"—you may be sure of that. A quiz requires work on the part of the student—even thought, if it is properly made up—and is, as a result, a very effective teaching device.

The student should do most of his work at home, of course; and the "shotgun" as first item on the daily agenda provides an incentive for him to do just that. Problems assigned for homework should always have the answers given; otherwise how is the student to know if he has solved the problem correctly; whether he has learned his lesson or not? The only reason for not giving them, presumably, is that the homework is to be handed in and the student given a grade on his accomplishment. This, however, I consider to be a waste of the instructor's time. Granted that most students do their own work at home, and that the only ones who derive any real benefit from a course are those who do their own work; there remain, despite eulogies of "honor systems" by the naive, the one or two or the few who will not. Not only may these few gain an advantage in the grades which, under the present system, the teacher must issue —these who of all should have the least advantage—but their bad example may encourage other impressionable youths to follow it. Careful correction and immediate return of such papers no doubt has value, though not, I think, in proportion to the time and labor devolving upon the instructor; but grades based on such material are meaningless and are not compatible with the teacher's moral obligation to society.

Another way of encouraging the student to work at home is to have the homework problems put on the board by individuals in the class. This has the disadvantage of occupying the teacher's time with one individual to the at least partial exclusion of the rest of the class; moreover, the student's method and explanation are often not the best and clearest.

Sending the whole class to the board has a similar disadvantage; the instructor cannot assist all who need help, except perhaps in very small classes, without wasting the time of the majority; nevertheless, it is very useful where adequate board space is available and when the class has no questions to ask and a quiz is not feasible.

Robert Hutchins, now president of the University of Chicago, is said to have greeted his first class on the first day with, "Any questions?" When there were none, he dismissed the class. On the second day, the same thing happened. On the third day, the class began to see the light, and thereafter he was bombarded with questions.

On the whole, this is a good procedure; but it does have at least one serious disadvantage. Ordinarily it will not be necessary to dismiss the class for lack of questions, but in engineering courses, the question is usually, "How

do you work problem 3 on page 245?" Not that working out the problem in such a case is bad—it is probably always helpful; but students seldom ask about the general subject matter, and frequently lack of understanding of that is the reason for their inability to work the problems. Too much emphasis on the problems permits development of the idea that the much prized and elusive answer, rather than an understanding of the principles involved, is the important thing. Sometimes a discussion of the reading matter comes naturally into the explanation of a problem, but more often the principles, stated as a formula, are simply used without a derivation.

Now, for the instructor to derive every formula which he finds convenient to use in the solution of a problem is to waste the time of all concerned when the derivation is in the text for the student to study at leisure; the thing is to get the *student* to do that. About the only way to do it is to ask the student to explain a step which is not obvious and which experience has shown causes the ordinary student difficulty. Such questions may be asked in class, or, perhaps preferably, included in a quiz.

Not only should frequent ten minute quizzes be given, but longer tests at intervals, covering perhaps a month's work, to refresh the student's memory, and final examinations at the end of the semester covering the whole course, are desirable. Psychological investigations have shown that learning is most efficient with respect to time spent, and is retained longest, when practice periods occur at increasing intervals of time; and is least efficient when practice is concentrated over a short length of time. The ten minute quiz—hour quiz—final examination series approximates the ideal in this respect, with the exception that quizzes on the material covered near the end of the course are telescoped together; however, this degree of concentration seems unavoidable under any arrangement of a single course.

The thorough final examination is perhaps the only good thing that American education can borrow from the European system, and that needs to be combined with shorter quizzes as suggested above. Many educators say that a final examination almost never changes the grade that the student would have received without the final. Even if all teachers found this to be true, final examinations would still be well worth while from the educational standpoint. A great deal may be learned or relearned in the review the student must undertake, and more from the actual taking of the test. A man may learn as much from writing one fairly stiff quiz as in listening to twenty lectures; writing the quiz requires thought and is an *active* participation in the educational process, while listening is passive and has been known to fall so far short of being stimulating as to be conducive to slumber.

Probably the commonest complaint voiced by employers of graduate engineers is that students are not taught to think in college. The quiz is the most potent instrument a teacher has for fostering the practice of thinking on the part of the student, provided that the quiz problems are so selected as to require something for their solution besides a memory for formulas, for the location of references, or even for methods of working given types of problems; they should require the exercise of reason. This can be done by making the problems sufficiently different from

those in the previous experience of the student as has been suggested earlier.

It shoud be recognized that a course so administered as to demand, through quizzes or any other means, thinking on the part of the student will never achieve the popularity of a "snap" course. For thinking is a painful operation for the majority of the human race, and causing a man to do it is unlikely to be regarded by him as a kindness at the time. The reader is presumed to agree that the achievement of the education of the student, rather than of popularity by the instructor, is the purpose of schooling. A teacher's effectiveness may be reduced if he is disliked by his students, undoubtedly; but no teacher need be disliked who will go out of his way to be fair and helpful, and this he should do in any event.

What has been said here concerning lectures and quizzes may not seem to apply to any but engineering problem courses. My teaching experience is confined to those, but my experience as a student is not; and I believe that almost everything said is applicable to other types of courses. In fact, I suspect that humanities and non-technical courses are the worst offenders in using class time for stenographic recording of lecture notes.

Again, what has been said may appear to have no application to laboratory courses. However, I believe all laboratory reports should be written under quiz conditions, and should emphasize less description of equipment and procedure than getting the data into useful form and drawing conclusions from it. Some pertinent questions should have to be answered as to the meaning of the experiment performed and as to why certain apparently incidental operations had to be included.

As for grading quizzes and reports, and assigning a grade for the course, one system is probably as good as another. However, the section of a university catalog stating that "A" is from 95 to 100, "B" is from 85 to 95, etc., is completely meaningless and should be torn out and thrown on the scrap heap. Most teachers know that for practical purposes it is impossible to give a quiz on which the "A" students will all make between 95 and 100, the "B" students between 85 and 95, etc.; and it is equally impossible to give a series of quizzes which will average that way. The absurdity of regarding an average of 70.1 as passing and one of 69.9 as failing is matched, on the other hand, by a method known as "grading on a curve," in which the lowest man in a class fails and the highest gets an "A". Most teachers, again, know that one class may be much better than another. In short, the teacher must use his own judgment, for which there is no substitute; this is a responsibility which he cannot conscientiously evade. "Curves" and numerical averages, of course, may be used to assist his judgment.

Laymen occasionally ask, "Why don't you just get a student assistant to grade your papers?" Supposing a capable assistant to be available, such practice would still be poor. In the first place, only if the instructor has graded the papers himself can he tell if a complaint made by a student upon receiving his graded paper is justified. More often than not, there will be grounds for any complaint; how is a grade to be adjusted then, if the instructor does not know how the other papers have been graded? Secondly, only by doing the grading himself can the instructor see what his students

have learned and what they have not; what points he should have emphasized more; which teaching tactics were successful and which not. Only thus can he improve his teaching; and, as the dean of a prominent engineering school recently said, a good teacher is always engaged in research in teaching techniques. There is always room for improvement; in the words of Ambrose Bierce, "The infallible teacher is still in the forest primeval, throwing seeds to the white blackbirds." Grading one's students' papers will, as a rule, readily remove any oversupply of self-satisfaction, as no one can fail to realize who has, as I have, found there that "The two most important types of welds are riveted welds and bolted welds," or been informed that "There is no stress in the member, merely 10 tons tension." No one points out to the teacher his mistakes; like those of the doctor, they are buried. If he does not discover them himself, they will be repeated in perpetuity; consequently, a good teacher must grade his own quizzes.

The important thing for one who would profess to be a teacher to remember is that teaching is only getting others to learn. Amiel, a thoughtful Swiss professor, put it this way: "All teaching depends upon a certain presentiment and preparation in the taught; we can only teach others profitably what they already virtually know; we can only give them what they had already." The verb, to teach, has no passive voice in actuality; no one can be taught anything—he must learn it.

Pity the "Ignorant" Engineer

By D. J. MACK

Assistant Professor, Administrative, University of Wisconsin

All of the current discussion and concern over the paucity of humanistic-social studies in the average engineering curriculum seems predicated upon the fact that the engineering graduate is far less well educated in the general sense than his contemporaries in other fields. Is this necessarily true? If not, may there be other reasons for the worry over the engineer's lack of well-rounded education?

Too many of us are prone to look with awe upon the allegedly well-educated Professor of Liberal Arts (for example) and yet how many readers have ineffectually tried to explain to this learned man the elementary difference between jet and rocket propulsion; or how many have attempted to describe nuclear fission to an honored member of the bar? Yet the commonest criticism of the engineer is that he is not "cultured" (whatever that connotes), and that he has no acquaintanceship with fields of human endeavor outside of engineering.

The inference also exists that today's graduate in liberal arts or business or medicine is a better educated individual than the engineer. There would be endless argument if one attempted to define what constitutes a well-rounded education, but we will assume that it means at least superficial acquaintanceship (not necessarily extensive knowledge) with all major fields of human activity including the physical sciences, natural sciences, arts and humanities, social sciences and business. In the world of today with science in all fields making such rapid strides, it is just as important that our well-educated individual be somewhat familiar with the physical and the natural sciences as with history, economics, political science, literature, etc. If we assume this to be a yardstick of the fullness of an education, let us see how well rounded are the graduates of non-engineering courses by examining typical non-engineering curricula. Recent catalogues of several large midwestern universities were consulted and the following results are typical. Only required courses will be commented upon, but in all cases (just as in engineering) electives are allowed which could presumably be used to fill cultural gaps in the required sequence of courses.

Pre-Medical. Adequate in the physical and natural sciences. Usually absent are courses in business, social sciences, arts and humanities although one language in addition to Latin is commonly required.

Commerce and Business. Weak in the sciences. Algebra is usually required although it is commonly listed as an alternate with science courses, which are required only of freshmen. A considerable smattering of courses in the humanities and social science is required of upper classmen in most options.

Journalism. Notably absent are the physical sciences except mathematics, which may sometimes be taken in place of the natural science. No arts course required.

General Liberal Arts. Almost impossible to evaluate because of the very large number of choices given the student in the selection of courses the first two years. If the student would conscientiously pick his courses to include those from all fields he would certainly acquire a broad education, but how often is this done? Usually students stick to one track in the selection of courses either because it is easier or because of preference for specialization. A sincere effort is being made by most schools to require majors in general liberal arts to schedule some courses from all the important fields of learning.

Pre-Law. The broadness of the pre-law student's education depends entirely on his Liberal Arts background. If he takes minimum Liberal Arts work, he may avoid many courses requisite to thorough education, but if he enrolls in a Liberal Arts Division of General Studies, requiring courses in the sciences, humanities, business, arts, etc., he will, perforce, acquire a much broader education.

Fine Arts. The narrowest of all curricula. Almost no courses are required outside of the particular field of specialization. Courses in applied arts are somewhat broader, usually including in the freshman year such alternates as "mathematics, biology or chemistry" and "history or language."

Education. Because of the large academic area covered and the tremendous number of courses offered, it is virtually impossible to arrive at a satisfactory conclusion as to the breadth of the curriculum from the viewpoint of well-rounded training. However, thorough perusal of the catalogue material from Schools of Education leaves several impressions: (a) graduates who receive teachers' certificates do take some work in nearly all fields; (b) a non-certificated graduate may specialize to the extent that he completely misses course work in fields necessary to thoroughly round out his education.

These sketchy summaries seem to indicate, therefore, that on a comparative basis the engineer is not nearly as inadequately educated as he is commonly supposed to be. The breadth of training received by the engineering graduate is certainly as great as that of his professional colleagues in medicine, law, or business and is larger than any of the others with the exception of the teacher group in Education and a specialized group from General Liberal Arts. Since the engineer is already receiving as general an education as his allegedly better-educated contemporaries, why all the fuss over increasing the humanistic-social content of the curriculum?

The desire to increase the "cultural" offerings in the engineering curriculum seems to be due to several causes. First, the mistaken idea as shown above, that the engineer does not get as many cultural subjects in his curriculum as do students in other fields. Secondly, a sincere effort to increase the scope of the embryo engineer's training and, by so doing, to enhance further his usefulness as a citizen and enable him to find his place more readily in today's social world. This is certainly a laudable and thoroughly defensible objective. Thirdly, some teachers of engineering in looking over their graduates sadly realize how little the graduates have availed themselves of the University facilities during their

undergraduate days, too many of them being merely engineering text-book-worms and grinds. The teachers vainly hope that by forcing these students of narrow, provincial outlook to take courses in the humanistic-social stem—presto!—upon graduation they become broadly educated cosmopolites. While it is true that sufficient exposure to cultural subjects may cause a "take" in a few cases, the old bromide about "you can lead a horse to water but can't make him drink" is still true in the majority of cases, simply because the average engineering student is a fugitive from humanistic-social studies. Fourthly, in line with the concept of a dynamic, constantly changing curriculum rather than a set, static one, it is stylish at the moment to change the curriculum in the direction of more humanistic-social studies, just as a few years ago it was stylish to lop off general underclass engineering courses in favor of more specialization in the individual curriculum.

All of this leads the writer to wonder if perhaps we are not over-accentuating the need for humanistic-social courses in the engineering curriculum. Might it not be more worth while to worry a little bit about the complete lack of cooperation in many Universities between the Engineering College and the other departments which give courses for the exclusive benefit of the engineering students? Many major professors and department heads have no idea what material is covered in fresh English or Chemistry courses, sophomore Math and Physics courses, junior Economics courses, etc. Perhaps even worthier of some worrying is the lack of cooperation of engineering departments among themselves—each department presenting its courses in its own way without regards for the interests of visiting students from other departments who must take the courses as part of their prescribed curriculum.

Perhaps if we put our own house in order first, and made better use of our curricula as they are now set up, we would realize that our students are getting a better all-around education than we think and that perhaps the engineer is not as "ignorant" as he is sometimes supposed to be.

Will Comprehensive Courses Meet the Needs of Engineers?

By A. L. PUGSLEY

Assistant Director, Engineering Experiment Station, Kansas State College

(Since January 1, 1947, Dean of Administration)

On the subject of comprehensive courses there appears to be no middle ground of opinion. Comprehensive courses are like tonsils. With tonsils, doctors are either for them or against them. Just as one doctor will declare that your tonsils are horribly diseased, and that only by having them removed can you possibly hope to live your allotted three score and ten, another doctor will violently defend the same tonsils as being the most healthy he has ever seen. In the final analysis you usually have to make up your own mind whether you want to keep them or not. So it is with comprehensive courses, you have to make up your own mind whether you favor them or not.

Since the committee of which Dean Hammond was chairman made its report recommending the liberalization of engineering curriculums somewhat over a year ago, there has been considerable discussion in engineering circles as to just what courses or subjects might be considered to fall within the 20 per cent classification of liberalizing subjects. Selecting these subjects and providing for their integration into the professional curiculum to the extent that each one will not be an isolated and unrelated bit is extremely difficult.

The problem which I wish to consider, therefore, is whether comprehensive couses can help to meet this need effectively. Before we go too far, let me define what I mean by a comprehensive course, for the term rarely means the same thing to different people, just as interpretation changed the meaning of the remark of the little girl who lived in Nebraska. When she was told that she was going to move to Kansas, she received the news in silence and then went out to look up at the sky saying "Goodby God, we're going to Kansas." Now the Kansas interpretation of her remark is that she said "Good! By God we're going to Kansas!"

As used here the term comprehensive course does not mean an attempt to cram several separate related or unrelated courses into a shorter period of time under one title. It does refer to a course which is designed to provide an introduction to the basic knowledge of a group of related subjects comprising a general field and providing sufficient detail in each to guarantee understanding of each of the related subjects. It is designed principally to show the homogeneous nature of the whole and the interrelationship of the whole with other branches of learning.

In a committee appointed at Kansas State College in the fall of 1943, there was almost universal opinion when the

committee began its work that comprehensive courses were unsuitable to the needs of most of the professional curriculums. I was a member of that committee and my reaction to comprehensive courses at that time was unfavorable. This reaction was based upon skepticism and a complete absence of study of the problem. Six months later the committee had studied the problem intensively, had met weekly for discussion, and had done a great deal of reading and research. At the end of this period the committee reviewed its original opinion and voted seven to two to recommend the installation of comprehensive courses at Kansas State College. It is interesting to note that the two dissenting votes came from members of the Department of Romance Languages and the Department of History. Their objections were largely to the effect that it would not be possible to incorporate adequate amounts of material in the time recommended. It is of interest to note that this objection was the first one made by every department approached in collaborating in the preparation of comprehensive courses. It is the usual reaction of any specialist in trying to convey an over-all approach of his field. Yet, these same department members have found this difficulty could be satisfactorily solved and have done so. The recommendations of the committee were that there should be provided four comprehensive courses. The one in the Social Sciences covered history, government, economics, and sociology. The one in the Biological Sciences covered botany, zoology, and microbiology. The one in the Physical Sciences covered chemistry, physics, geo science, and astronomy. The one in the Humanities covered music, painting, sculpture, architecture, literature, and philosophy. These courses each carry four credit hours per semester. The faculties of the various schools have adopted one or more of the comprehensive courses in various curriculums. There has been no insistence that they be incorporated into any curriculum. Reactions of the students vary, but the majority opinion of the students who have taken a comprehensive seems to be favorable toward it.

The information and understanding of the field gained from a comprehensive course should provide the student with the ability to grasp and orient significant facts and ideas in this field both while in school and afterward. It should, in a sense, provide a framework where the student for the remainder of his life will find many pegs on which to hang and niches in which to place new facts and new ideas. The comprehensive course should develop an appreciation for and an interest in the field of knowledge. Perhaps more than other types of courses it should be a springboard of incentive and should provide the base or starting point from which the student can extend his range, depth, and detail of knowledge and appreciation in that field.

A comprehensive course should not be assumed to provide the detailed basic or foundation knowledge needed by a student who would become a specialist in that field. But it does open up new views that the engineer would never otherwise gain. For the engineer, in my opinion, the comprehensive course represents the best opportunity to acquaint himself with the broad areas of human knowledge outside of his professional field with the smallest loss of time. Singleness of purpose is a desirable quality in the engineer, but when pursued to the exclusion of all else, it

results only in narrowness and later in his inability to relate his work to the complexities of our economic and social system. That engineers and scientists feel the need to make their convictions felt is most aptly shown by the recommendations of the scientists and engineers who developed the atomic bomb. The engineer uses fact as his basis for opinion within the scope of his profession. Too often he is autocratic when dealing with matters outside of his profession.

It may be concluded, therefore, that society and the individual would benefit if the professional groups had a better picture of the influence of their profession upon the economic and social structure of the nation together with a realization of their social responsibility. Further broadening by acquaintanceship with other cultural fields will contribute richly to the effectiveness of the professional man. The professional student should be encouraged to consider that such knowledge is an essential part necessary to complete his own field. The limitation of time for such additional subjects makes necessary their selection with the greatest of care, and it may be argued that any presentation which will provide an area of knowledge which is interrelated and presented as a unified whole will prove most effective as well as time saving. For students other than professional, this broad approach could be amplified with profit both as to scope and intensity.

There are those who argue that the place for these courses lies in the last year or years of the curriculum. Opposing this stand are those who assert that early inclusion, or at least continuous inclusion, of liberalizing influences throughout the curriculum is more effective than leaving them until the last. Also that for students who drop out before graduation without achievement of technical competence, the early inclusion of some liberalizing courses will benefit the individual and society more than having taken incomplete technical work alone. However, in no part of the curriculum should the inclusion of non-engineering subjects overshadow the student's feeling of progress and accomplishment toward his professional goal. Nor should there be sacrifice of technical competence.

Educate Industrial Engineers for Action *

By G. B. CARSON

The Selby Shoe Company, Portsmouth, Ohio

This paper is based on the premise that industrial engineering education as it is conducted at the present time is not the perfect education for young industrial engineers. We emphasize the word "young," because after a man has left college for a period of ten years or more, the experiences of his professional life tend to become governing and seem to direct his career more than his undergraduate education directs it. We must, therefore, concern ourselves with that part of his career directed by his undergraduate education . . . his first ten years out of college.

The fact that in industry generally there is a lack of college trained professional personnel in methods and standards departments, in production control, in quality control, and in other related manufacturing problems, indicates that something must be lacking either in the education of the young industrial engineer or in the opportunities afforded him by industry.

Objectives of Industry

We must re-examine the objectives of American industry. The welter of cockeyed economic theories, of political intrigue, and of dogmatic pronouncements from governmental agencies during the period of this War, has somewhat obscured industry's real objectives.

Let's examine the facts. First, industry must be stable. Without stability, it cannot endure, progress, perform a service, maintain employment. We immediately, then, must examine what it is that makes industry stable. It takes no profound analysis to see that steady, reasonable profits make for stability. When profits are too high, management tends to become hog-wild, perhaps even a little "crack-pot" in its ideas, and sooner or later the top ownership of the company becomes careless.

When profits are too low, the industry is forced to eliminate all non-direct charges from its cost ledger, and sometimes, therefore, becomes exceedingly vulnerable because its competition has better methods, better promotion, better working conditions, and, in short, a better product.

Obviously, then, reasonable, steady profits can be stated as the primary objective of industry. These profits result in that industry's ability to maintain and improve its competitive position, and allow it to spend the necessary funds to develop new methods, new products, and new merchandising programs.

How, then, can the industrial engineer assist industry in attaining its major objective?

* Presented at the Conference on Industrial Engineering, S.P.E.E. meeting, St. Louis, June 20–23, 1946.

The Place of the Engineer in Industry

A recent survey made by Dr. W. E. Wickenden, of Case School of Applied Science, and published in the April issue of the *Case Alumnus,* revealed some interesting facts concerning the position of engineers in industry. Of 5,504 alumni of Case School of Applied Science for whom occupations were known, it was found that 2,012 were in administrative positions; 1,778 in professional positions; 1,575 in military service; and 139 in miscellaneous unclassified occupations. Thus, it can be seen that a surprisingly large percentage of all engineering graduates ultimately get into some form of industrial administration. Not all of these graduates surveyed have training in industrial or mechanical engineering. The survey embraced all fields of engineering. In spite of this fact, 36.6 per cent ultimately found themselves in administrative posts. It is reasonable to assume, therefore, that if a survey had been made for industrial engineers only, a correspondingly larger percentage ultimately would have found work in administration.

The industrial engineer, therefore, must be an administrator if he is to cope with the statistics showing his ultimate position in industry.

From a number of contacts, and from personal experience, the industrial engineer must also be prepared to render technical service to industry in most of the following categories:

1) Plant design, including supply of plant services.
2) Production control.
3) Cost control.
4) Methods development.
5) Product development.
6) Labor relations.
7) Quality control.

Other services can be mentioned, but the foregoing are so important that they should be stressed. They should become part of the industrial engineer's background.

The industrial engineer necessarily overlaps other fields. A perusal of the above shows that he overlaps the mechanical engineer in the category of plant services. He overlaps the personnel department in the category of labor relations. He overlaps the student of business administration in production and quality control. Such overlapping is not to be deplored. On the contrary, it is to be encouraged. The industrial engineer must be able to operate successfully within the confines, or the looseness, as the case may be, of the organization in which he finds himself.

The Tasks of the Industrial Engineer

We must now examine what it is the industrial engineer does, actively, in each industry in which he finds himself. A complete detailed discussion of the personal experiences of the many kinds of industrial engineers we find is impossible. We can, however, make a breakdown of the average picture, and may find it somewhat helpful in planning our program. The tasks of the industrial engineer, as I see them, are as follows:

1) *To determine what the problem is—immediately.*

In too many cases, we do what by analogy might be called swatting flies. There are two ways to take care of the presence of flies: One is to use a bigger and better fly swatter or chemical means of extermination; or, the other is to repair the screens so that the flies cannot get in. All too frequently

in industry today, the management is "squatting flies." It is the duty of the industrial engineer to perceive the problem clearly enough so that he can find the "holes in the screens" and repair them.

2) *Facts concerning the problem must be uncovered—quickly.*

Many engineering professors and students of engineering think that a measure of greatness in engineering is to be able to handle the highly scientific—the extremely complicated—the highly mathematical problems. I believe we have ample evidence to prove that this is not generally the case. One of the most important attributes which should be possessed by the average industrial engineer is the ability to perform a quick analysis to ascertain the facts necessary to solve the problem which he faces.

In many engineering schools, it has been the policy to provide the student with the data he needs to solve a problem. The data are given to him, procedure is outlined, and he thinks it through and writes a report. He all-too-frequently misses the tremendously important fact that when he is in industry, it is he who must obtain the data from a welter of facts *and fancy,* and must put it to use quickly enough to avoid costly mistakes or continued improper operation.

3) *A complete course of action must be planned—rapidly, and then the engineer must ACT.*

Industrial engineering students frequently are referred to in industry as the boys who design the forms and write the reports. Important as report writing is, and as helpful as proper form drafting may be, these are but a small part of the industrial engineer's job. If someone were to ask what is the most important single attribute an engineer should possess in the 1946 industrial picture, there could be only one answer—ability to follow through.

The course of action of which we speak here means detailed planning, not only from the point of gathering facts to the conclusions in the report, but also from the conclusions to the finally completed *and operating* job. Unless the recommendations of the industrial engineer are carried out, and unless they indeed do show savings and improvements in the industrial process involved, they avail us nothing. It is only through actual operation of a newly-suggested plan or program that industry saves enough money to pay the industrial engineer's cost and still have some left over.

4) *Conclusions must be drafted from partial data.*

Engineers all too frequently try to get all the data necessary to point out a conclusion. This is not possible in industrial engineering. Frequently we are able to determine only two of seven variables intelligently and well, but we still must make a decision and continue production. The engineer, therefore, should be taught both analytical and inductive reasoning, although we must appreciate, at the outset, that these attributes are probably inborn characteristics more than a learned science or art.

One industrialist made an especially strong point of the fact that he would rather be wrong

doing something than be right doing nothing. His thesis was that to be wrong doing something a few times ultimately resulted in progress, whereas, to be right doing nothing frequently lets the passing stream go by, and ultimately results in a poorer position in industry.

5) *Instruct—sell—exercise pscyhological warfare—keep the operating crew interested in the new methods and the new proposals.*

It is not enough to conceive and see that a new program starts operation. Constant pressure must be exerted on all such jobs until they become set enough in the routine of the plant to avoid any possibility of sliding back into old habits or refusing to follow the new methods or new procedures.

Many industrial engineers lose interest in work which has been concluded—they think—and fail to realize that it is only by continuous operation of the proper programs they have set up that a company makes money.

It is most important to stress the psychology of re-instruction in the training of industrial engineers. By that we mean constant re-selling of an idea. If possible, the psychology of the salesmanship should be so carried out that the supervision and the workers in the plant both feel that they have a part in the development of the new program. Further, it is quite important that both supervision and workers feel that some measure of the new program, at least, is their own idea.

Industrial engineers also frequently ignore the fact that many good ideas can come from the operating personnel. Sometimes these ideas are not well-conceived, nor are they well-planned, but they may be the germ of a considerably better plan which the industrial engineer can carry out if he will but listen patiently to the operating crew.

6) *Endless follow-up.*

This point is purposely being be-labored because it seems to be so continuously ignored in engineering education. One who spends most of his time with people of relatively high intellectual attainment, and with relatively high regard for scheduling, frequently misses the necessity for follow-up. We must always bear in mind that in the life of an engineering school there is the constant disciplinary factor of final grades which will spur people on. This may provoke a few smiles, because I know, as well as most of you, the apparent apathy of certain students toward getting things done. But, student apathy is amateurish compared with the apathy, the passive resistance, the disinterest, and the ineptitude of the average factory production worker. In the main, factory supervisors are not much better. Frequently one finds an entire factory without a single analytically or logically minded supervisor on the staff. The only appeal which can be made to these people is an emotional appeal. The industrial engineer must be prepared to understand the type of mind he encounters here, and to know the best and quickest method to get

that mind to react properly to his newly-conceived ideas.

The man who can get things done quickly and properly is worth far more to an industry than the highly-learned technical graduate who can analyze, examine, and draw conclusions without follow-through.

Salesmanship for the Industrial Engineer

There has been much general information published concerning salesmanship training for engineers. In many cases it has been rather abstract in nature and frequently ignored by engineering college personnel because there seems to be nothing tangible about it.

I am not so concerned here with salesmanship as an art or a science, as I am with salesmanship as a necessary part of the industrial engineer's ability. Those of you who are familiar with the pedagogy of salesmanship will know how to put the subject across better than I.

The first requisite is ability to sell the industrial engineering program, as such, to top management. The appeal cannot be made from the principle of scientific exactness. It cannot be made upon the principle of a better place in which to work—a better plant. It cannot be made on the principle of a smooth-working organization. The reasons are simple—steady profits do the talking. Any factory manager can cite example after example of a business which has an old building, unadvanced methods, and yet maintains a steady year-to-year earning power.

The industrial engineer must, therefore, constantly pepper top management with reports on annual savings achieved by methods in effect conceived by him. He must also propose every new project to management on the basis of savings anticipated. This must be done by striking a keen balance between presenting all of the facts and being so concise that the management will devote some attention to it. Nothing in industry is more aggravating than long, involved reports. It is necessary for the industrial engineer to say what he has to say in a very few words, with few figures, and few pictures or drawings.

The foremen in the plant must be sold on the fact that the industrial engineer is *assisting* them. He must also be psychologist enough to realize that if he gets the idea of assistance to the foreman across, he will in turn receive considerable help from the foreman in ferreting out bottlenecks, bad methods, and improper procedures. If the engineer does not achieve such a feeling between himself and the foreman, the foreman is very apt to regard him simply as a meddler who is always trying to change established methods and make work harder for him (the foreman). The engineer must always bear in mind that to change procedures, change methods, change specifications, leads to a host of difficulties in manufacturing. Unless he is mindful of this fact, he will always meet frustration in attempting to get his new ideas established.

The industrial engineer must have the rudimentary information necessary to deal with worker psychology. His approach here should be the fact that he, as an engineer, is applying scientific methods to get the worker a square deal—an hour's pay for an hour's work, and extraordinary pay for an extraordinary day's work. This is about the single basis on which he can sell himself to the worker, and he should be apprized of this fact. En-

gineering instructors are in an enviable position. They can look objectively at the problem of selling an idea to the worker without actually becoming embroiled in the day-to-day energy-consuming debates that take place in the plant. They should, therefore, be able to direct the mental processes of those men who must engage in the debates along the proper channels.

Apparent Shortcomings of the Average Graduate Engineer

We shall not try to deal completely with shortcomings, nor shall we try to note here the many advantages the graduate engineer has over the non-engineering graduate.

For the sake of brevity, we list the following most apparent shortcomings of the graduate engineer:

1) Impatience with the "grass root" details of the average industrial problem.
2) Lack of ability or desire to talk *with*—rather than *to*—a worker . . . to study his viewpoints and motives . . . and to make him *want* to do it that way.
3) Lack of fight—of pioneering spirit—to accomplish his purposes against great odds, and to tread down the uncharted pathways of industrial organization and management.

Conclusions

We all know that industrial engineering education as it is carried out today has an impressive record. It is definitely not a failure. But, it could go so much further. It could be of much more benefit to the industrial engineer, himself, and to industry, if a few of the foregoing facts were known and understood.

Discussion of Papers

Given by PAUL N. LEHOCZKY
of Ohio State University
AND
G. B. CARSON
of The Selby Shoe Co., Portsmouth, Ohio

E. L. Grant (Stanford University): Do you have a conventional introductory management course in there?

Paul N. Lehoczky: Our course I.E. 601, the "Management of Men," and course I.E. 602, renumbered 710, dealing with the "Laws of Management," include both the introduction to management from a historical point of view—Fred Taylor and on up, the basic principles of management, and the personnel phases of management.

R. D. Sloan (State College of Washington): There are two questions I would like to ask here. One was a repetition of the comments on the elimination of a course in heat power, thermodynamics, or whatever you want to call it. The other is—apparently there's no course in statistics. Is it true that that course in statistics is included in some of the others?

Professor Lehoczky: To answer the first question first—Industrial En-

gineering, historically, is an off-shoot of mechanical engineering, and in a large number of schools it is still under the control of the department of mechanical engineering as an industrial option. That, from our point of view, usually leads to an over-emphasis of the orthodox Mechanical Engineering courses, which are essentially in the heat-power category. Now, when we began, we had to take heat power, machine design, heat power lab., and a few other courses into our curriculum, because the people who set up the curriculum were essentially from the department of mechanical engineering. Gradually we dropped those courses and replaced them with courses which we considered to be of greater importance, which were broader in the industrial sense and not as specific from the point of view of any particular subject. Heat power usually dealt with some power plant problem and it usually degenerated into the consideration of a subject matter which in our opinion is extremely specialized. We felt that there were much broader courses to be taken.

DEAN SLOAN: So you have no thermodynamics except that in physics?

PROFESSOR LEHOCZKY: We have an additional course in physics—5 credit hours—which will stress thermodynamics, from the physics point of view —correct.

DEAN SLOAN: Was that the same reason that prompted you to leave out fluid mechanics?

PROFESSOR LEHOCZKY: We never have had a course in fluid mechanics, but a student may choose it as an elective. We always did have a course in dynamics, and the student has a certain choice between dynamics, fluid mechanics, and advanced strength of materials. But, we are going from the specific toward the general in the basic sciences and we probably could not get this treatment in the M.E. Department. We still take machine design in the M.E. Department, and almost as much as the Mechanicals take. We still take "Materials" in the M.E. Department, and exactly the same amount as the Mechanicals take. What was the second question?

DEAN SLOAN: In regards to a course in statistics.

PROFESSOR LEHOCZKY: We have no organized course in statistics. We do sandwich the question of frequency distributions, etc., into a Control Charts course. Wholly inadequate—we know that, and we sometimes send our students to another Department to take some Statistics. I mentioned in the paper that we might have to replace the extra physics course with one dealing with Statistical Mathematics. We have a course in Waste Elimination which we hope will work into "Quality Control," especially in view of what was said here last night about importance of "Quality Control." However, that is a matter for future development.

M. B. ROBINSON (Fenn College): To what extent do you get into the problems of tooling and tool design, in connection with your methods development?

PROFESSOR LEHOCZKY: There are three courses dealing specifically with tooling. The subject is also covered in our two machine shop courses; the student touches on it in the time and motion study laboratory, and then he comes in contact with it again in the redesign of a "design" from the designer's point of view to the production point of view. There is also a course in Tool Engineering, which covers tooling in detail.

V. D. PRIAN (Fenn College): It might be over-simplification, but I was wondering what your reaction would be to giving the Mechanical Engineering Department, the fields of heat power, design, and production. And giving Industrial Engineering—management, production, and design. Of course, as I said in the beginning, it's all over-simplification, but don't you agree with that basic fundamental idea?

PROFESSOR LEHOCZKY: I don't know about Mechanical Engineering because the Mechanical is specializing in a lot of things today, but I agree fully as to your definition of the Industrial Engineering phase.

W. R. SPRIEGEL (Northwestern University): What's the nature of this Graduate Seminar you have included in the fifth year?

PROFESSOR LEHOCZKY: Those students who are graduate students to begin with, and those fifth-year students who carry dual registration—registered both in the College of Engineering and in the Graduate School—attend a special seminar. The seminar involves problems in Industrial Engineering. I think it's best explained by saying that it involves such principles as are expounded by Filipetti in his recent book, and in the bringing in of certain recent advances in some of the fields as well as some of the phases that were not in the courses outlined here.

PAUL T. NORTON (Virginia Polytechnic Institute): I'd like to ask Dr. Lehoczky two questions. I don't know whether he can answer the first one or not. What is the E.C.P.D. situation in regard to Heat Power? Have they said anything about the dropping of Thermodynamics from this curriculum?

PROFESSOR LEHOCZKY: No, they haven't.

PROFESSOR NORTON: Have the changes been accredited?

PROFESSOR LEHOCZKY: No, they haven't. I suggest that E.C.P.D. could well reexamine all of the curricula in all of the schools, because things have changed since their last examination. We would welcome an inspection.

PROFESSOR NORTON: Well, the other question is of particular interest to us as a military college, where, in normal times, 95 per cent, or practically 100 per cent of the able-bodied students take military for four years, including Advanced R.O.T.C. during the last two years. What do you do in the case of your Advanced R.O.T.C. students?

PROFESSOR LEHOCZKY: The Advanced R.O.T.C. student, unless he wants a graduate degree, may use his credit toward his "elective" requirement.

PROFESSOR NORTON: Do you consider that a non-technical elective?

PROFESSOR LEHOCZKY: No, it probably will have to be considered a technical elective, and incidentally, the question is now before our faculty, open to debate. Many members of the College of Engineering faculty are of the opinion that it could be considered as a fifth year technical elective. In the past, the Advanced R.O.T.C. student carried 18 credit hours of R.O.T.C. work, for which he received nine credit hours toward his degree under the heading of Electives. Our Council on Instruction will not consider Advanced R.O.T.C. as "broadening" hence it will have to be counted as technical. One group of the faculty wants it to be added to the total on top of all the other requirements. I don't think that will happen.

PROFESSOR NORTON: Well, our experience has been that they have been getting about half as many credits as

hours put in, although the hours that they put in may not be quite as difficult, hour for hour, as the others. There's been some talk in our staff that it might be considered as non-technical, or humanistic, or that sort of thing, the idea being, of course, that you can use R.O.T.C. in full substitution for the broadening electives.

PROFESSOR LEHOCZKY: Our Council on Instruction, which is an over-all committee for the University, basing its judgment upon the principles set forth in the S.P.E.E.'s Hammond report, examined everything that was claimed to be broadening in terms of that report. It refuses to designate military training as broadening.

PROFESSOR NORTON: This is a subject that, knowing a little something about the way it's been carried on in our school before the war—I feel is a pretty good technical elective.

H. R. BEATTY (Pratt Institute): Should this curriculum or some other one be used to train the men who are interested in the sales end?

PROFESSOR LEHOCZKY: Our men—perhaps 10 per cent of them in the past—have gone into sales engineering as a life vocation. In almost all instances, the sales part of it, and in many instances—in most instances—the technical part of their work was taught them by the company. In other words, the Cincinnati Milling Machine Company or any other firm—would take the man and train him to be a sales engineer. Except for such general basic courses as speech, cost analysis, special research work—for which we have a course in the fifth year—we are not going to specialize in sales engineering as such. Are you referring to the man's developing a nice sales personality, or to his technical knowledge?

PROFESSOR BEATTY: Technical knowledge—sales engineering, as such. You know, twenty years ago a mechanical engineer was trained to be an industrial engineer by industry in the same manner that you now speak of training the sales engineer for industry, by the company itself. In fact, I was graduated as a mechanical engineer and was trained by the General Electric Company as an industrial engineer. And today we're in the same position as far as training sales engineers is concerned. We are leaving it to industry, rather than doing it in the schools, and I was wondering if in the five-year curriculum, you couldn't, perhaps, cover this branch of the field.

PROFESSOR LEHOCZKY: We're simply trying to train a broad professional man, and if we try to train a sales engineer, or a man capable of engineering sales, we wouldn't know where to start, because we don't know where he's going to start to work and with what company. If he went with Warner & Swasey, definitely, he'd have to have an entirely different type of technical training than if he went with another type of company, such as the General Electric Company.

CHAIRMAN: I think perhaps we ought to give Dr. Lehoczky a little rest now and ask for any discussion or questions regarding Mr. Carson's talk.

M. B. ROBINSON: I have a question that cuts across both of the speakers' talks. Mr. Carson enumerated as one of the responsibilities of the industrial engineer the task of product development, and the new curriculum at Ohio States leaves out the formal course in machine design—I'm not sure whether you still have kinematics and kinetics, which usually leads up to machine design. You do have the mechanics of strength of materials, of

course, but I just wonder if leaving out the machine design is in any way in conflict with the acceptance of product development as one of the duties of the industrial engineer.

PROFESSOR LEHOCZKY: We don't leave it out—we have nine hours of machine design. It's thermodynamics we left out.

PROFESSOR ROBINSON: I'm wrong, then—I understood you to say you were leaving out machine design.

PROFESSOR LEHOCZKY: No. We're actually increasing materials and machine design, at the expense of thermodynamics. We have more machine design now—nine credit hours of it.

C. E. BULLINGER (Pennsylvania State College): I'd like to suggest this comment on the last question. I'm not entirely sure what Lehoczky is after, but I think I know what he's after. What he's after is what I choose to call the manufacturing design aspect as opposed to functional design aspect. I think that's what he was driving at. Certainly, if the industrial engineer is going to be mixed up in processes and all the rest, they've got to do it. Now, it appears to me that during the war, there's been a dove-tailing of the two functions, that is, functional design and manufacturing design have been brought together.

PROFESSOR BEATTY: I'd like to point out that there's still a third thing, and that is dependent on what the public wants designed, which is the job of this sales engineer that I spoke of before, and which needs to be done by an engineer instead of some of the folks who are now attempting to do it, and who lock horns continually with the engineering department because the engineer says he can't build it that way, and these people say that the public doesn't want it any other way. We have to have people who know enough about what the public wants and to design, to bring those points of view together. We have been working on our courses with the view to having sales engineering, industrial marketing and industrial design, and we are planning in our operating fund now for an arrangement which actually calls for the men to go into the field, the sales engineering field, and actually make an analysis, under the leadership of the member of the faculty in charge, to do some original work, to create a job, and at the same time cover the other fields.

PROFESSOR BULLINGER: Lehoczky has dropped out his thermodynamics. This is analogous to what we also did about four or five years ago. We dropped out our second course in thermodynamics and substituted for it what we choose to call industrial heat transfer, on the argument that the industrial engineer, in his regular work, has to deal with heat in different forms, and with problems of transferring heat, and all sorts of problems such as heating, drying, air conditioning, and the like, and I wonder whether he expects to get that all covered in a physics course, or whether he would leave it out, because he doesn't consider it necessary. I would also ask Mr. Carson the same thing, whether he thinks that also might be a field to be covered for industrial engineers.

PROFESSOR LEHOCZKY: There has been a good deal of criticism—and I notice the thermodynamics end bothering these folks here—about emphasis here and emphasis somewhere else. I don't know how many of our industrial engineers are interested in air conditioning, or run into heating problems. I don't know whether or not we could prepare them to adequately cope

with those problems by a simple course in thermodynamics. In other words, this whole problem of how far we can specialize is the one that worries us. The man in the fifth year has a good deal of latitude—I think it's twenty-two hours—of elective work—and if he wants to take thermodynamics in that period, that's all right—we'll suggest it to him. But we don't consider thermodynamics, as such, a basic part of Industrial Engineering. We may be wrong and we'll change our minds if we are. That's our fundamental concept so far.

PROFESSOR BULLINGER: Well, I didn't want to specialize in air conditioning. What I am concerned with, however, is that the students do get a pretty good background in heat transfer, which they don't ordinarily get in most courses. I think thermodynamics courses are mostly power propositions, rather than what I outlined. What are you going to do in an industrial establishment where you have heat problems—like this man's problems here and in other plants where he has to heat things up, or in plastics operations? Certainly the Industrial Engineer ought to have sufficient background to know some of the fundamental principles—unless you can get them in physics.

PROFESSOR LEHOCZKY: We don't know just what we will be able to get in physics yet. But, you see the direct transfer was made from thermo to electronic controls, and I might argue with you that these are as important, if not more important than the particular thing that you're arguing for. It depends on the future of the student—if we only had a blue print of a man's future. If Prior, sitting here, took all of our men to Goodyear, we'd know exactly what to teach them.

PROFESSOR ROBINSON: I'd like to ask what is taught in the first two courses of electrical engineering. Are those survey courses by Dr. Oldfield, or is it basic fundamentals of service?

PROFESSOR LEHOCZKY: They are the standard, almost nationally taught, electrical engineering for non-electricals. I know I had them at Case, and almost the same thing is done here at Ohio State. The chemicals, the mechanicals, and industrials—and I think the metallurgists, all take the same courses. I believe they use Kimberly's textbook.

G. L. TUVE (Case School of Applied Science): We are not doing that at Case any more.

PROFESSOR LEHOCZKY: They aren't? Well, I'm sorry—it's been some years. Our third course deals with Electronic Controls.

G. B. CARSON (The Selby Shoe Co.): May I add comments there? In the shoe industry, in which there are fewer engineers per employee than in many other industries in the country, we find that it's extremely important to have a man familiar with plant services—my term—"plant services"—may not have been clear. We have humidification problems, de-humidification problems, heating problems, air movement problems, dryer design, and allied projects. We don't expect a man to have courses specifically on these points of application. We would like to have the man well enough grounded in fundamentals so that he can tackle problems objectively and come up with an answer **quickly,** because we can't spend a year getting a solution.

You gentlemen may not realize what goes on in some of the soft goods industries. Right now, we have currently in production approximately six hundred and fifty models, and those six

hundred and fifty models are put into production in more than a million possible combinations.

As a result of change orders, we sometimes have less than a day to get set up to run through a special lot. And when that special lot is done, we don't use that equipment again for another season. The man who designs the equipment and puts it in can't be too profound in his deliberations, because, if he is, the product is made and shipped by the time he comes in with his report.

There's a very fertile field in the soft goods industry, for engineers. Engineers have always regarded the soft goods industry as beneath their dignity. They don't want to have anything to do with it, outside, of course, of the schools that are located in areas where they have textile engineering courses. So, we have a problem that's peculiar to our particular industry and isn't exactly similar to the problem found in the metal trades.

M. L. BEGEMAN (University of Texas): I'd like to get back to curricula for a minute. I think most of us realize that engineers as they get through college don't always know where they're going. In other words, they can't do a great deal of specializing while they're in college. Now, with that point in view, isn't it a good idea to make an engineer a good general engineer, so far as we can? I criticize the curriculum that has been presented to us today, in that it lacks thermodynamics. Now, in a period like we're in now, there are plenty of opportunities for a man to be placed. But, in a period of recession, perhaps we are going to cut out some of these fellows, and they're going to have to get another job. They won't be equipped to take a job, say, that an electro-mechanical engineer would have. The same objection, I hold, is true of the tool engineers, the tool engineering curriculum. I think he should first have a general engineering course and then specialize, say, in graduate work, or in the senior and graduate levels. And I think the same applies to industrial engineering.

PROFESSOR LEHOCZKY: May I answer this? I realized that there would be a lot of trouble about thermodynamics, and I would appreciate it very much if you would tell me how many people feel we made a serious mistake in dropping thermodynamics from the curriculum?—(*Twelve people feel that a serious mistake was made by dropping thermodynamics from the curriculum.*)

PROFESSOR LEHOCZKY: Thank you. I was rather interested in the comments. I have never yet had a single alumnus tell me that he ever used the principles for thermodynamics. I'm glad to have your reactions. Now, is there anyone else who feels that we should *not* have thermodynamics, at the expense of something else, now?—(No one in the audience voted for the elimination of Thermodynamics.)

PROFESSOR LEHOCZKY: Very well, I'm all alone and Thermo goes back into our curriculum.

V. D. PRIAN (Fenn College): The talk which Mr. Carson gave us was most interesting and inspiring. One thing bothered me a little bit. In most student bodies, it's one thing to teach techniques, and another thing to teach action. So, what I would like to ask Gordon—How could you expect, or how would you teach action to cultivate or inculcate the philosophy that you just covered?

G. B. CARSON: I think one of the ways that we can do that is to provide certain experiments or projects on

which we do not give the data, but make the student, himself, get that data. At Case, we did it with friendly companies. (1) We made the boy—in methods engineering, for example—go out and get his own project, and we took particularly "cocky" fellows and sent them out to companies that we knew were definitely anti-methods engineering minded, and made them sell the idea of getting the project from the company. They also had to sell the use of a motion picture camera in a union shop. It was then necessary for the student to present the results to both the management and labor.

PROFESSOR PRIAN: In other words, throw them in and let them swim—right?

MR. CARSON: Well, actually, that was the impression the boy had. He thought he was in there swimming. But, in some cases we quietly prepared the way.

W. R. SPRIEGEL (Northwestern University): Mr. Carson, did you mean to include product design as a primary requirement of the industrial engineer?

MR. CARSON: No, it was included in my list of technical functions he performs.

PROFESSOR SPRIEGEL: He has very little to do with it.

MR. CARSON: In many shops he does. In some other shops, he has to get into it through the back door.

PAUL T. NORTON: What Mr. Carson has just said makes me want to ask him a question. As an industrial engineer, does it make sense to him that in a mass production shoe factory they should make so many models? Really, no industrial engineer would consider it good manufacturing from the industrial engineering angle.

I want to relate something that might make him feel better about the shoe industry. When I first started to do some work some years ago with a southern furniture manufacturing association, there were two engineers in the business—a great big industry, scattered over the whole south, doing at that time about a hundred million dollars worth of business. And those two engineers, while they were graduate engineers, weren't doing any engineering. They were executives—top executives. There are a few more of them in the industry now. But, it seems to me that one of the things that the southern furniture industry has always done very well is standardization. You can't get anything special. There are lots of other things I'd like to see them prove, but it seems to me that when you want special customer articles, those articles should be made in some other place than in mass production. I'd just like to ask Mr. Carson if he is able to answer those questions.

G. B. CARSON: Yes, I'll take your questions one at a time. First, we deal in *women's* footwear. Now, you're not going to tell Janie that she has to wear model 4 black because it's easier to produce it that way. We're getting over into the field of foot millinery. Many of our shoes are not intended to be worn out—we hope they don't wear them out—and when we make foot millinery instead of shoes, we can make Janie look very obsolete when she walks down the street in the shoes she bought three months ago. And that's why we're planning, as a shoe industry, to produce six hundred million pairs of shoes in the calendar year 1946, in spite of the leather shortage. So, we're mixed up in the style industry, and when you are mixed with style, you

have to do things as an industrial engineer that you don't like one bit.

What we have tried to do is segregate our production into subdivisions. We're planning now to produce all of our so-called "orthopedic" type shoes in one production line—all of our so-called slip-lasted or casual type shoes in another production line, and we've been able to get some very startling and substantial savings by that procedure. And we're constantly working with the sales department to get them to stop being so "wild-eyed" about what they demand of the factory. Have I answered your question?

PAUL T. NORTON: Yes, I think you have, and I might just say—to take one more word or two—that the furniture industry is very conscious of style changes. They make radical changes in appearance. In fact, the patterns there last no more than six months. But, the average southern furniture factory will not run, at any one time, more than six to eight styles, and you either get that or you don't get it. And that, of course, is what makes for economical production.

G. L. TUVE: I'd like to ask Mr. Carson about the cost control item that he included in his list. It seems to be on the edge between engineering economy, accounting, and the industrial engineering work. How can we best include that in our instructions program?

G. B. CARSON: We want young men to be able to analyze a cost chart, and then find out what makes that cost go up. His ability to take a balance sheet and understand it—not having just so many figures in front of him, but, rather, a clear picture of cause and effect there—is very important.

For example, one of the men in the cost control field looked at the balance sheet one month and said, "Well, it's very obvious here that our supply procurement is out of control. And he was right. He picked it up from the cost chart. So, we'd like a man to have creative ability enough to look intelligently at a profit and loss statement, cost breakdown charts, budgets, and decide what it is he can do about it.

G. L. TUVE: Can you suggest any correlation which might be carried out in engineering colleges that would bring out such a result? We seem to be going at it from three or four different angles.

G. B. CARSON: I think the best way to get at it is to use friendly companies in your area, to have a man come in as a lecturer, take the last balance sheet that has been published, because that no longer is secret material, break it down and show what it was that caused certain of the trends, particularly if he can bring some charts with him. Try, then, to take the problem made up as a case study, using the principles of good pedagogy, and have the students then solve the problem.

H. R. BEATTY: I have a brochure on salesmanship here, and I never hesitate to bring it in whenever the topic might come up. I was an industrial engineer in a large utility company, and had the job of organizing and training some 200 engineers to be salesmen. They did not want to be salesmen, of course. They didn't know anything about it. They came to me and told me so. They'd rather take a "licking" than try to sell anything. But, it wasn't a choice with them any more. There was no engineering work to be done, and the company thought that, rather than lay them off, they might do something about them as salesmen. We put them through a three months' training course

in salesmanship. The result was that many of them said they'd never go back to engineering. The idea of getting out and meeting people and learning what's going on in the world rather appealed to them. Now, possibly if those boys had had something along that line in school, they could have gotten off on the right foot to start with, rather than spending several years in a closed engineering job, before they were forced into it.

Graphical and Analytic Methods as Applied to Aircraft Design*

By STEVEN ANSON COONS

Chance Vought Aircraft Co., Stratford, Conn.

The aircraft company with which I am associated devotes itself exclusively to the design of combat aircraft and it is our constant aim to make our airplanes the fastest flying airplanes in the world. This we seek to accomplish in two basic ways—by increasing the power that drives the airplane—and by improvement in the aerodynamic qualities of the surfaces of the airplane that come in contact with the airstream through which it flies.

In the very beginning of aircraft history, scant attention was paid to what we now call aerodynamic cleanness, because in those days the problem was to sustain a heavier than air device in the air, and for the very low speeds at which they flew the box kite principle was perhaps entirely adequate. But certainly in the intervening years we have seen a remarkable and significant change in the whole basic philosophy of flight engineering. It has become more and more obvious to us that an airplane travels on and by virtue of its airwetted surface, and any and all improvements of this surface that result in lowered resistance to its passage through the air and increased ability to sustain weight, are direct improvements of the airplane device.

This problem of the surface of an airplane is a geometrical one, and probably if aerodynamic considerations were the only variables which we had to take into account, we could arrive at an explicit solution of the problem with comparative ease. But of course, a combat airplane must be able to carry something: it must carry the pilot who guides it, and the engine that drives it, and the fuel for the engine, and guns and ammunition, and armor plating to protect the pilot from enemy gunfire, and landing gear, and all the control systems that make it possible for the pilot to actuate the various mechanisms in this complex device. Moreover the air forces which act on the surface of an airplane together with the inertial forces of its component parts, and the driving thrust of the engine, must all be balanced by means of beams and webs and stiffeners and other structural elements.

These then are the considerations of space within the aircraft surface, and they are diametrically at variance with the aerodynamic considerations outside that surface. Hence we are unable to achieve a best solution, and must be content with a most favorable solution or resolution of all the variables involved. The design of an airplane surface is a compromise solution.

* Presented at the fall meeting, New England Section, A.S.E.E., October 5, 1946.

Indeed the design of almost any part of an airplane is a compromise, and often it is very difficult to decide what importance to attach to each variable in the group of variables that affect the design, since these variables are all of different kinds. The excellence of an airplane design is measured by how successfully it has been compromised.

That is why the airplane is designed on the drawing board primarily by graphical methods. The drafting department of an aircraft company is the hub of all the design activities that take place there. Structural analysis, aerodynamics, power plant analysis, weights —all these groups are like spokes of a wheel, and they must meet and coordinate their efforts at the drafting table. Until a tentative design is drawn, none of these groups can function. So the draftsman is really the main spring of the design procedure. His job is to make a graphical analysis of a problem of great complexity, having many variables of many different degrees of importance. Toward the goal of making the most favorable solution of this problem, he is guided by the various specialists, but he himself has a specialty all his own, and the principal tool with which he has to work involves many phases of the synthetic and analytic geometries.

Thus at the very beginning of the design stages for a new airplane, the draftsman makes a sketch of a proposed airplane, showing general shape, arrangement of major components, wing configuration, and so forth. This sketch is usually about one-twentieth of the full size of the airplane, and several different versions are drawn. These drawings are examined by aerodynamics, and by the heads of the engineering design department. After discussion, one or two designs are selected for further consideration. Aerodynamics prepares a tentative performance calculation of these design studies, in which an attempt is make to predict how fast such an airplane can fly, how far with the fuel capacity proposed, how fast and how high it can climb, and all the other aspects of flight behavior of an airplane. Possibly these tentative calculations influence or even precede the sketches. The chosen design is then elaborated to the extent that major structure is roughly mapped out (just to make sure that the airplane can be built), and the shape of the surface is determined and fixed so that a small model may be made for display purposes. On the basis of these preliminary design studies certain guarantees can be made to the prospective customer, and finally official sanction is obtained to proceed with the design and construction of a new experimental airplane.

The original shape is now analyzed in more detail: the weights department prepares a balance analysis which may possibly move the wing with respect to the center of gravity of the fuselage, and a new design sketch is accordingly drawn. A more detailed analysis of the structural requirements indicates that possibly a beam must pass through a region previously reserved for a fuel bag, and the design must be accordingly changed. The engine manufacturers now send in new information on the proposed power plant, and it is found that the engine is four inches longer than prevous information indicated. This results in a major change of fuselage length, but with this new length it is found that the angle between the ground and the airplane at certain flight attitudes during take-off is such that the landing gear must be lengthened. But now it is seen that due to the relocation of fuel, the change in the engine and fuselage, and the change in

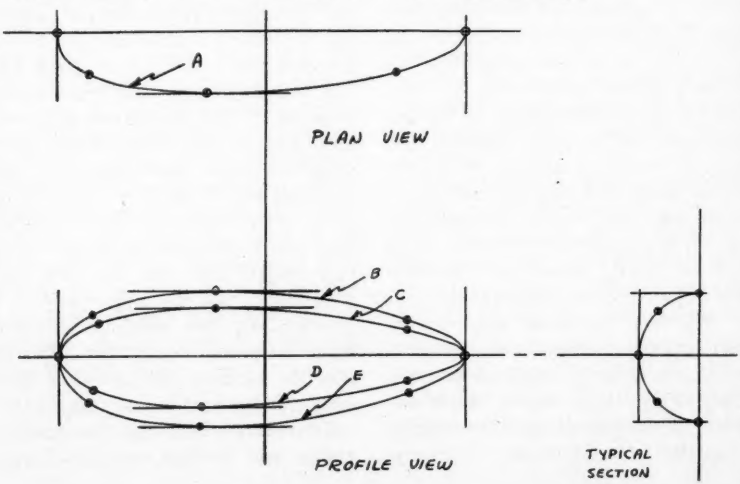
the length (and therefore weight) of the landing gear, the balance of the airplane has again changed, and the wing must be relocated.

With every change in the design elements, there is often a corresponding change in the surface of the airplane, and the surface must be redefined in considerable detail so that other draftsmen who have been called in to work on the project may know how much room is available for ammunition boxes, guns, ducts, radio equipment, controls and primary structure. Thus every change in design influences to a greater or less degree all other parts of the airplane.

Finally, after many changes, the geometrical surface or lines of the airplane are fixed and determined, and except for minor unforseen contingencies, they are not likely to change much any more. These lines are then drawn full size to a high degree of drafting accuracy. We draw these surface lines on sheet iron on which is screened a thin uniform coating of white paint. We scratch through this coating with a sharp pointed scriber, exposing a thin line of bare metal, and we then blacken these lines by painting them with copper sulfate solution. The result is a permanent and accurate drawing of fine black lines on a white field which is not susceptible to dimensional variation due to change of humidity or aging. The lines are drawn to an accuracy of plus or minus five thousandths of an inch wherever possible.

In the actual development of these lines and surfaces we use the principles of projective geometry to construct curves to define sections of the airplane. We do this because we can fit such constructed curves to almost any desired shape; we can define such curves by only a few points, and indeed we can define an entire fuselage by means of only a handful of dimensioned points in space; we can keep pace with the rapid changes in the shape which, as we have seen, occur during the stages of preliminary design; and finally we can use analytical methods to calculate the position of a point on a surface so defined to any degree of accuracy we wish.

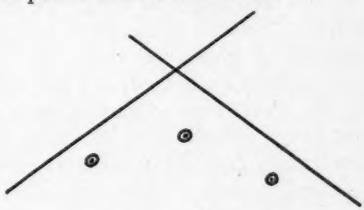
Thus if we are discussing the shape of a simple fuselage,



Here the line A is completely defined by five points and three slopes (implied) and similarly for the lines B, C, D and E. These lines then define points on any section taken through the fuselage, and the surface can be drawn in only one way provided we abide by the rule that any section is composed of second degree curve segments (or, which is the same thing, point rows of second order as constructed by means of projective geometry).

In a plane, a second degree curve (or a point row of second order) is uniquely defined if we know any five facts about it. Thus if we have five points in any configuration, we can find the point row of second order which passes through these five points by the geometry, graphically, or, if we wish, we can find the equation for the curve by purely analytical methods. Naturally the graphical solution is much quicker and much less labor than the analytic solution, and for preliminary design work we would invariably use graphics. Thus graphically we can solve the following problems:

These configurations fall into either of two categories easily recognized in projective geometry. The first three uniquely determine a projectivity between sheaves of rays and dually the last three uniquely determine a projectivity between ranges of points. The first three yield to the principles embodied in the theorem of Pascal; the last three can be constructed if we make use of the dual theorem, the theorem of Brianchon. But there are other configurations possible which uniquely determine a projectivity (a point row of second order) or second degree curve. For example, we might find it necessary to construct a curve tangent to two lines and passing through three points (a total of five known facts), but with the points and lines discrete:



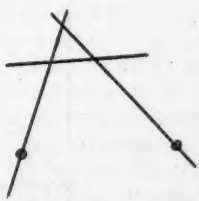
FIVE POINTS

A POINT SLOPE
& 3 POINTS

2 POINT SLOPES
& A POINT

FIVE SLOPES

A POINT SLOPE
& 3 SLOPES



2 POINT SLOPES
& A SLOPE.

In this problem we encounter difficulties as soon as we attempt to apply either the Pascal or the Brianchon theorem. Yet we instinctively know that a solution exists, and indeed we can justify such a belief if we want to take the time to set up a set of simultaneous analytic equations and determine the unknown constants by the rather laborious process of their evaluation. Fortunately, however, such questions *can* be handled graphically with no particular difficulty and so we can expand the original set of six configurations to include a large group of more general configurations, and in our design work there is no telling when we may be called upon to deal with some one of them.

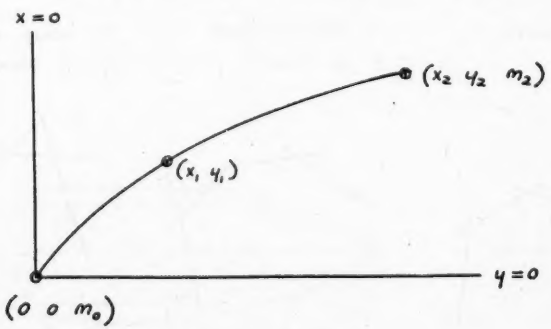
In the final stages of design we use analytical methods to calculate the coordinates of points on these curves, since the lines are to be drawn full size, and the sheer labor of manipulating a long heavy straight edge to construct these curves graphically, together with possible inaccuracy which may attend these mechanical difficulties, make analytics the more convenient tool. I will show you a typical example of the work involved in deriving the constants for an equation of an actual curve on the surface of one of our airplanes. This curve represents a line on the airplane which is the widest point for each section cut in station planes. It is a profile view of what we call the maximum half breadth line of the fuselage. If the sun were shining directly down from overhead on the fuselage, the surface above this line would be illuminated, the surface below it would be in shadow. In passing I might mention that the geometrical interpretation of light and shade on the surface of our airplane has its place in aiding our design, since appearance of these surfaces is important too.

The axes are artificially chosen as shown so as to simplify the arithmetic of the solution.

We can assign numerical values determined from the small scale graphical layout, to the literal terms and we have this list of facts:

$$n_0 = \tan 12° = .21256$$
$$n_2 = \tan 5° = .08749$$
$$x_1 = 40 \quad y_1 = 7.4$$
$$x_2 = 87 \quad y_2 = 12.6.$$

Then we make an operational sequence chart for easy calculation:



Step	Operation	Result
A	$n_0x_1-y_1$	1.10240
B	$n_2x_2-y_2$	−4.98837
C	$B-n_2x_1+y_1$	−1.08797
D	AC	−1.19937
E	$\frac{y_2}{x_2}$	.144828
F	Ex_1-y_1	−1.60688
G	F^2	2.58206
H	$-\frac{D}{G}$	.464505
I	E^2	.020975
J	$HI-n_0-n_2$	−.0088539
K	$2H$	.929010
L	n_0+n_2-kE	.165503
M	$H-1$	−.535495
N	n_0B	−1.06033

Here each operation can be performed on a standard calculating machine in one setting of the dials. The equation for the curve in implicit form is $Jx^2 + Lxy + My^2 + Nx - By = 0$ and the corresponding numerical values selected from the chart give

$$-.0088539x^2+.165503xy-.535495y^2 -1.06033x+4.98837y=0.$$

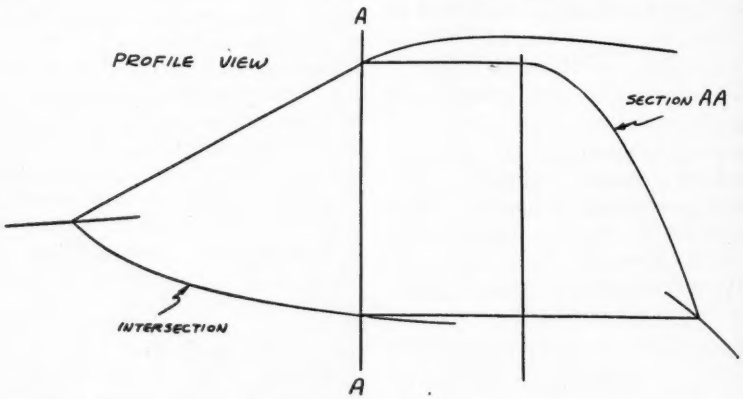
These operational sequence charts are simple to use, and the actual calculation work can be entrusted to a calculating machine operator who knows nothing about the actual algebra of the process. In fact, there is another device which we use to further simplify the procedure, so that each operation is indicated by an arrow pointing to the correct numbers in the column which are to be added or multiplied to yield the next result in the column. With the use of this scheme even a person who is unfamiliar with the use of the calculating machine can turn out the right answers.

We have also a simple sequence chart for obtaining the explicit form of the implicit equation, and another chart for evaluating the dependent variable for a series of values of the independent variable, once the explicit equation has been formed. The analytic treatment has been reduced to simple routine operations, and it is no task at all to calculate the various sections of the surface of an airplane with very great accuracy. We can then lay out graphically the shapes of these curves from prepared tables of coordinates, confident that they will, when taken together, define a surface whose shape is exactly what we intended it to be.

Most of the surface of an airplane is a surface of double curvature, but there are portions of the surface which are of single curavture, that is, capable of being formed from a sheet of paper by simple bending without distortion or tearing. These surfaces are portions of a convolute. Such surfaces are found on the wing, where we have a wrapped surface between a section at the tip and section at the root. Such surfaces are also often found in the windshield portion of the cockpit enclosure. The optical properties of transparent materials are better if the shape into which these materials are formed is as simple as possible, and therefore, windshield shapes are made in the form of surfaces of single curvature instead of surfaces of double curvature so that the forming of such shapes can be as easy as possible and so that the distortions involved are as slight as possible. If the surface is of single curvature, a flat sheet of glass or transparent plastic may be heated and allowed to drape itself over the form by virtue of its own weight; if the surface were one of double curvature considerable force would have to be applied to compel the transparent material to conform to the desired shape.

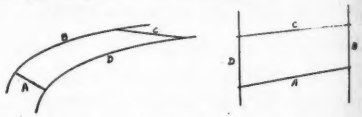
In generating the surface of a windshield we usually design an intersection line on the surface of the fuselage and a

curve in the plane in which the windshield and sliding canopy separate. We design the intersection line we want because it has so much to do with the appearance of the airplane. Then geometrically we find the straight line generators of the surface of single curvature which will yield these two curves.

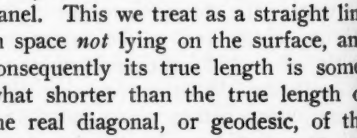


Afterward we proceed to draw the shape of the doubly curved canopy which will fit against this windshield shape and "fair" into it.

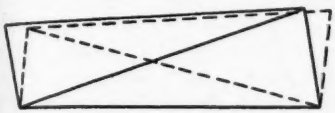
Another problem in connection with these surfaces of single curvature is their "development," or the determination of the flat pattern of skin (with rivet holes all located in it) which will exactly fit the curved surface. This is important in the case of a wing, because if we know the flat pattern accurately, we can make the skin panels of the wing in quantity, and each of these panels will fit the rib and stringer structure inside, and all rivet holes will line up so that they can be readily assembled. This is done by means of triangulation, a geometrical process with which I am sure you are all familiar. In passing, however, it might be interesting to mention a simple scheme by which we seek to improve the accuracy of the result. If we have a portion of a wrapped panel on a wing:



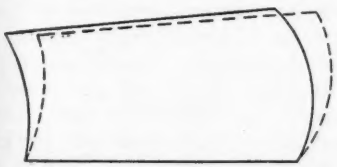
We can determine the true lengths of the straight generators A and C exactly. The portions of the contour curves B and D show true lengths already, and need only to be straightened. But the true length of a diagonal lying on this surface cannot be determined exactly, since we cannot plot it on the surface. Instead we determine the true length of a straight chord going diagonally from corner to corner of the panel. This we treat as a straight line in space *not* lying on the surface, and consequently its true length is somewhat shorter than the true length of the real diagonal, or geodesic, of the panel. So the panel when laid out would look something like this:



We then find the true length of the other diagonal chord. It too is shorter than the real diagonal curve, and when superimposed we have two shapes:



The true shape of the panel is then somewhere between these limiting possibilities, and we may assume that it is halfway between them. This yields a result which is entirely adequate as regards accuracy. Actually we develop a series of panels with one set of diagonal chords and then develop all the panels with the other diagonals, and split the difference between the two resulting superimposed figures.



On an airplane we seldom use ruled surfaces other than the convolute, because such surfaces are convex in one direction but concave in another, or anticlastic, and we prefer surfaces which are synclastic, or convex in any section (except in the case of fillets). That is, we do not want the airplane to be "sway-backed" or saddle-shaped. But it is well to have some knowledge of such surfaces, since in the design of surfaces of double curvature sometimes we get "sway-backed" effects unless we are able to recognize certain danger signals which warn us that conditions which will lead to a ruled surface are present.

For example, in a fuselage, when the longitudinal curvature becomes small, there is a great danger that the shape will become anticlastic in certain regions so that we might unwittingly create a surface, one of whose longitudinal sections looked like this:

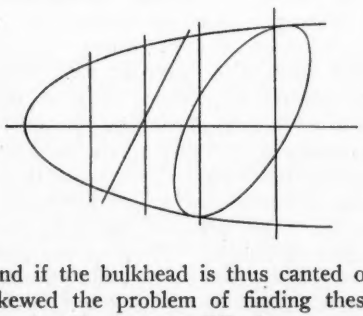
Apart from the unpleasant appearance and poor aerodynamic qualities of such a shape, the skin of the airplane will have a tendency to "oil can" between rows of rivets; it will be effectively unsupported except where a rib or stringer is attached to it. At high speeds such a surface may commence vibrations which will rapidly grow in magnitude until we have dangerous amplitudes and the airplane may even disintegrate in mid-air.

Sometimes we make flat patterns for sheets of skin which will fit surfaces of slight double curvature. We do this by making certain assumptions as to the behavior of a flat sheet of thin metal when it is forced by rivets and attachments to deform itself to become a surface of double curvature. Naturally such solutions are approximations, but we are able to make them with sufficient accuracy to get usable results. This gives us two very desirable advantages. First, we are able to save the cost of the dies and forming fixtures which would have to be used to preform the flat sheet, together with all man hours spent in such forming of every sheet, and secondly, a flat sheet drawn down over frames and stringers until it becomes a surface of double curvature is "tighter" and cleaves to the interior supporting structure much more avidly than it would if it were preformed. Consequently the tendency to "oil can" is very much reduced.

We encounter many interesting geo-

metrical problems in connection with surfaces of double curvature. We are frequently confronted with the task of developing intersections between two such surfaces, or between a surface and a plane. Sometimes we must generate a wrapped transition surface between two separate surfaces of double curvature in such a way that the wrapped surface will be tangent to each of the two given surfaces (like wrapping a sheet of paper around a fooball and a grapefruit).

We have to determine slopes of surfaces in various directions, so that we can indicate on our drawings the exact angles to bend the flange of a bulkhead to make it fit against the skin. Sometimes the bulkhead does not lie in a plane parallel to those which we have used as sections to define the shape of the airplane (we call these planes station planes),



and if the bulkhead is thus canted or skewed the problem of finding these bevel angles is more difficult.

To facilitate the fabrication of longitudinal members in the airplane, such as stringers, longerons, it is advantageous to choose their shape in such a way that they may be made straight with no twist. This may be done when the surface in which they lie is wrapped (of single curvature) because then the longitudinal may lie along a wrap line of the surface.

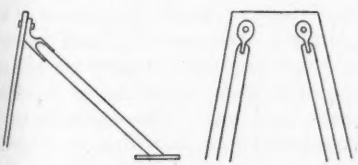
When the surface is doubly curved, the longitudinal lying on the surface cannot in general be straight. But it should be so located (if such location is dictated by shape) that it may be made by bending only in one principal plane, with no bending at right angles to this plane. Now such location, to fulfill purely geometrical conditions, may violate other requirements of structural strength, or conditions involving the simple mechanics of riveting or bolting the member in place. So the final solution of the problem will involve a compromise guided by an exact knowledge of the degree of twist and unwanted bending introduced.

When the design of the airplane has reached its final stage, and all paper drawings which show the design ideas are approved, we make exact full size drawings of major assemblies on sheet metal as I have already described. Here the graphical space analysis of the positions, shapes and clearances of all parts, no matter how tiny or insignificant, is performed with the aid of descriptive geometry. Thus it is vital to know whether a bolt can be placed in its hole without interference with some adjacent member; to tell exactly the shape of a small clip that joins a stringer to a frame. You might think of this work as a process of actually building the airplane in drawings to make sure that it will all go together, and to determine exact sizes and shapes of all parts. The process can be performed much faster and cheaper in the drafting room than it could be in the shop, with the workman cutting each part to fit.

Finally, from these metal master assembly drawings we prepare a set of paper detail drawings of each part of the airplane, and the design work is then complete. If the experimental

airplane proves out, we go into production.

Inside the surface of the airplane we have geometrical problems of a different nature—problems which might be characterized by the term "straight line and plane" problems. Thus the structural tubing of an engine mount would be in such a category, and the theoretical center lines of the various tubes would first be established in space, and then the actual intersections of the tubes of various diameters would be found so that each individual tube could be cut to exact shape and size for welding together. An overturn structure comes to mind as an example of a problem of this kind.



Here the problem was to make the forged fittings identical for left hand and right hand, since to make them mirror images of one another would double the cost of the dies, and dies for forgings are very expensive. In fact, this problem of making two identical parts fit on both the left hand side and the right hand side of the airplane is constantly arising, since wherever possible it cuts our costs in half.

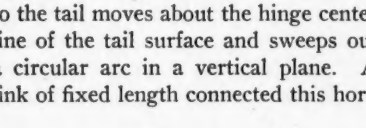
The surface controls of an airplane—those that flap the ailerons and elevator and wiggle the rudder and extend the slots and flaps—usually involve cable and pulley systems, and each pulley must be supported by a bracket of suitable strength and rigidity, attached to a bulkhead or other interior member. The center lines of these cable systems must, of course, be chosen in such a way that they do not run through the radio console or the oxygen bottle, and so the geometry of these cable systems often becomes rather elaborate. Here again the location of pulleys and brackets and cables is not left to the shop to determine after everything else has been located in the airplane, because, for one thing, they are decidedly *not* makeshift affairs, but are contrivances of extreme importance which must be very carefully designed so that the forces which they transmit are safely sustained at the support brackets. This can only be done by accurate structural analyses based on accurate geometrical information.

Then there are the class of problems which might be called rotation problems. A landing gear linkage extends and retracts the wheel by virtue of the rotation of the various elements of the linkage about certain axes. The extended and stowed positions of the landing gear wheel do not often lie in one plane, and it is necessary to determine the axis of rotation that will allow a link of fixed length to carry the wheel from one position to the other. This problem is solved in the preliminary design stages by graphical methods in small scale, but for the finished airplane it is usually computed analytically since the space required for a full size graphical analysis would be too great and the degree of accuracy must be high in order to permit accurate design of the forgings and castings involved.

A portion of the cowling on one of our airplanes is made of material that is a half inch thick formed so that its outside surface is a portion of a convolute. In this cowling there is a door which hinges so as to provide access through this cowl. In the design and drawing up of this door we had to decide upon a method of cutting the edges so that it

could readily be made in the shop—this required an elementary knowledge of what can and what cannot be done in machining—and we had to decide whether the edge of the door should be generated by a cutter moving along but always normal to the surface or at some fixed angle relative to some base plane of the cowling. Then, after this, we had to open and close the door graphically in order to be sure that the clearance and fit were satisfactory. Now you will notice that such a problem involves several geometrical notions. We have a three dimensional figure of medium complexity to begin with—and we cut this figure by means of new generated surfaces which correspond to the cutter moving relative to the work—and then we rotate this whole figure about its hinge line to verify the clearances that we expect to find in order that the door will work properly. Needless to say the axis of rotation of the door was, as usual, skewed in all views. The final drawing was a complete and exact picture of the desired part, which when built, worked the first time without any necessity for trimming and fitting on assembly.

Another typical rotation problem concerns a four bar linkage in space. In the control of the horizontal tail of one of our airplanes, a horn connected to the tail moves about the hinge center line of the tail surface and sweeps out a circular arc in a vertical plane. A link of fixed length connected this horn



to another link which sweeps out a circular arc in a plane which is not parallel to the plane of the horn. This is a four bar linkage in space,

and for every position of the driving link we are able to predict the corresponding position of the driven link, and thus draw a motion analysis diagram which will enable us to tell whether or not such an arrangement is feasible from a structural point of view, and whether it gives us suitable accelerations of the moving parts.

Objects are seldom in simple positions in space relative to one another in an airplane—they are very often skewed and misaligned so that they are not in the same plane or even in parallel planes, and this is what makes airplane drafting so much more complicated and difficult than the drafting of machine design, since in this kind of work it is possible and desirable with relatively few exceptions to arrange the machine elements simply with respect to one another.

An airplane contains also various arrangements of piping which conduct air, taken in by scoops in the airstream, to the carburetor, to the prime movers for cooling, and recently with the advent of jet turbines and true jet engines, to the interior of the engine itself. Naturally these pipes conduct air at very high velocities, at least in the inlet stages, and so they must be designed so as to offer least resistance to its passage. Often too the areas of these pipes or ducts must be adjusted so that they fulfill the thermodynamic functions of a diffuser, gradually changing the high velocity and low pres-

sure of the entering stream into lower velocity and higher pressure with as little energy loss as possible. Now an ordinary stovepipe would scarcely be a refined solution to such a problem, and a good duct like a good fuselage or wing must have aerodynamic cleanness. Moreover it is important that we be able to predict the area of any section of such a shape and change it if necessary to conform to certain theoretical requirements. We can read off cross sectional areas by means of a planimeter, of course, but if we use second degree curves to define the shape of each section it is extremely easy to calculate these areas, and if we need to adjust them to some other value, we can predict what the new shape must be in order to yield the new required area. This is, of course, primarily an analytical process which we use to enable us to achieve a graphical result. Indeed in the whole design procedure analytical and graphical methods go hand in hand, each a complement of the other. They are inseparable, and a complete discussion of descriptive geometry and projective geometry cannot be given as applied to aircraft problems without an introduction of many analytical concepts and methods.

In these days of higher and higher speeds the things I have said about the aircraft industry from my point of view also apply, I think you will agree, to all the phases of the transportation industries in general. Our automobiles are no longer simply motorized democrat wagons, but are copying the airplane in cleanness of line and sweetness of surface. Our railroad trains, our busses, our subway cars are all evidencing the influence of streamlining. Boats have always been streamlined shapes, and indeed they have been crudely streamlined since antiquity. The ship's mold loft is a department which now has a counterpart in principle at least in every aircraft plant in the country.

I have tried to bring to your attention the high ranking importance of graphics, and analytics as applied to graphics, in the design of the modern airplane. I should consider my time well spent if I could convince you that this importance is of the same order as the importance of chemistry to the petroleum industry, or the importance of the science of electronics to the communications industry. Certainly each is the fundamental tool of its field, and perhaps from this standpoint you see a justification for such a comparison.

Our company is constantly employing young men who are recent graduates of engineering schools. In view of the course of training which each must receive under our guidance before he is equipped to undertake with competence even the simpler problems of graphics, I venture to suggest that the colleges have two important basic responsibilities. First, they must present the subject of graphics to prospective engineers in such a way that it maintains a deserved dignity in the eyes of the student. He must see the subject not as a mere extension of a manual training course in mechanical drawing which he took in high school, but a usable important tool which he can ill afford to be without. The subject must be shown to possess what I shall call "academic aristocracy" because our young engineers tend to be intellectual snobs who will respect a subject only if they think the ideas it embodies are on a lofty intellectual plane. It must be shown to be a modern and growing subject rather

than an ancient and static one incapable of further expansion. And finally it must be shown to be practically applicable, since young engineers are often prone to avoid the purely theoretical.

The second responsibility is to encourage research and development of new methods and principles in the field of graphics. There is just as great possibility for discovery in this as there is in any other science. As graphics becomes a tool more and more in use, more and more problems arise in connection with its application. It is continually expanding and the problems call for newer and better solutions.

I think we delude ourselves to some extent when we say that we can train a student to think for himself so that if we equip him with a meager group of broad fundamental principles he can by himself solve any problem that arises in his work. Those students who are able to do this are decidedly in a discouraging minority.

Nor is it possible to cram a mind with all the possible problems and all the possible ready-made solutions to them, and from the vantage point of the college it is hard to anticipate precisely what kind of work the student will be doing and what exactly his problems will be. Industry is becoming an ever-increasingly complex field, and jobs in industry are becoming more and more varied and at the same time more and more specialized.

The alternative is to give the student a broad knowledge of what is available and how to go about the task of availing himself of it. If an engineer knows that certain problems exist, have been successfully dealt with, by what means, under what broad classifications of thought, then when a problem of similar nature confronts him, he will neither attempt a clumsy solution of his own when the matter has been skillfully dealt with by experts, nor will he seek back in his crowded memory for the answer he learned in school. He will instead be able to select precisely the right reference sources and will find there either the explicit solution he needs, or a system of principles and thinking which will enable him to achieve a solution with a minimum of originality and intellectual effort.

A New Method of Axometric Projection

By D. MAKSYMIUK

Instructor in Mechanical Engineering, University of Saskatchewan

It is sometimes necessary to show an object by a single projection or view, and for this purpose isometric views are most frequently used because they are easy to draw. It is generally conceded that an axometric view is more pleasing to the eye. In axometric projection the three principal axes are foreshortened to different ratios of their true lengths; for example, the length projection may be foreshortened to $\frac{7}{8}$ of the true length; and the height projection to $\frac{2}{3}$ of the true height; the foreshortening of the third axis is then fixed by the other two. The methods used in making axometric projections are laborious because of the preliminary constructions necessary to fix the directions of the three axes and to provide scales to be applied to them.

Herein is presented a method of axometric projections which gives the exact foreshortening of the axes, obviates the preliminary constructions necessary with other methods, and is yet simple to apply.

The Problem

Draw an orthographic projection of the object shown in Fig. 1 so that the length dimension be foreshortened to $\frac{7}{8}$ of the true length and the height dimension to $\frac{2}{3}$ of the true height.

The Construction

The plan and elevation of a line MN making an angle α with the horizontal and β with the vertical plane are drawn first. The plan of the object is drawn with the length axis perpendicular to the XY line. From each point in the

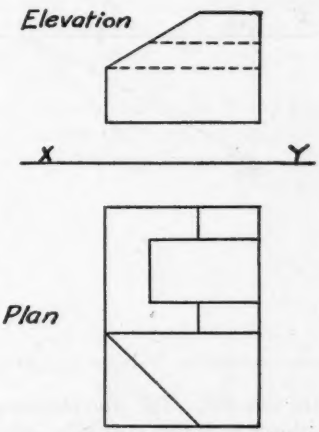


Fig. 1.

plan projection lines are drawn parallel to mn. A point O is chosen on the projection line from o, and using it as center and with a radius equal to $\frac{7}{8}$ of oa, a point A is located on the projection line from a so that the angle oOA is greater than 90°. Then with center O and radius $\frac{2}{3}$ of the true height, a point B is located on the line oO, and from B is drawn a line parallel to OA. Some convenient point on OA is chosen as o' and with it as center, and the true height as radius, a point b' is located

THE SOLUTION

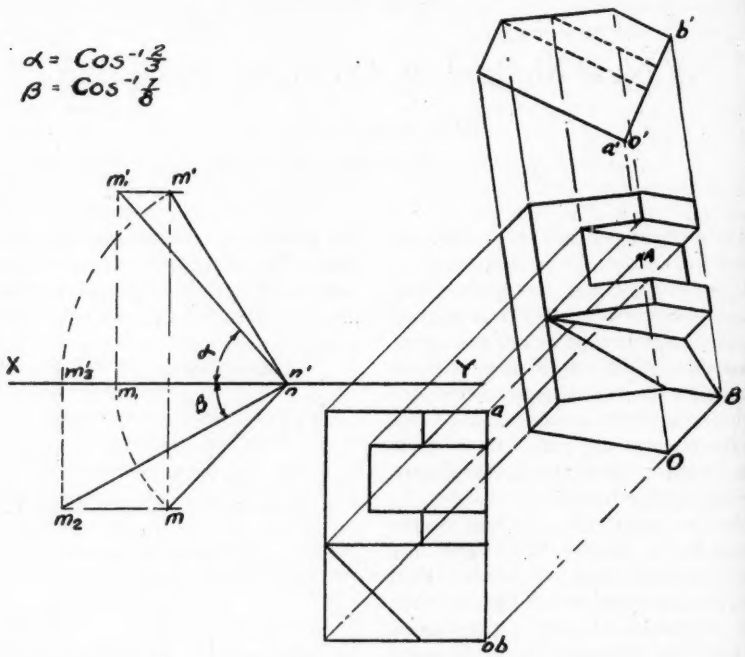


FIG. 2.

on the line Bb'. The true elevation of the object is drawn correctly with respect to $o'b'$ and the required projection is obtained by projecting the plan and elevation parallel to aA and $b'B$ respectively.

THE EXPLANATION OF THE PRINCIPLES INVOLVED

In order to follow the development of the method used in Fig. 2, three constructions commonly used in Descriptive Geometry will have to be reviewed.

1. If a point A be projected orthographically onto two planes (which are not necessarily at right angles to each other) and one of the planes be then rotated about the trace into the plane of the other, then the two projections a and a'_R will lie on a straight line which is perpendicular to the trace.

2. If a line is perpendicular to a plane, then the plan of the line is perpendicular to the horizontal trace and the elevation is perpendicular to the vertical trace of the plane. The converse is used to find the traces of a plane having certain inclinations to the projection planes. For example, if it be required to draw the traces of a plane which is inclined at 40° to the V.P. (vertical plane) and 60° to the H.P. (horizontal plane), then projections are first made of a line which is

perpendicular to the required plane and therefore makes 50° with the V.P. and 30° with the H.P. The traces of the oblique plane are then drawn at right angles to the plan and elevation of the line. The construction is shown in Fig. 4.

It will be noticed that the angles the traces make with the XY line are not the same as the inclination of the oblique plane towards the planes of projection; also that there are four sets of traces corresponding to the four attitudes that the oblique plane may have towards the projection planes when it is inclined towards them at given angles.

3. The third construction is the rabattement of an oblique plane about one of its traces.

In Fig. 5 below the oblique plane is shown by V.T. and H.T. and it is rotated about the H.T. using the edge view. The following points should be realized:

(a) that the edge view shows the true inclination of the oblique plane towards the H.P.;

(b) that when the oblique plane has been rotated to coincide with the H.P., a line, such as V.T., contained by the oblique plane, will, when rabatted, be in position $V.T_R$;

(c) that a line outside the oblique plane, such as OX, will, if it maintains its position relative to the oblique plane during the rotation, be shown in the new position by Oj_R;

(d) that the true shape of any figure in the oblique plane will be seen in the rabatted position of the plane.

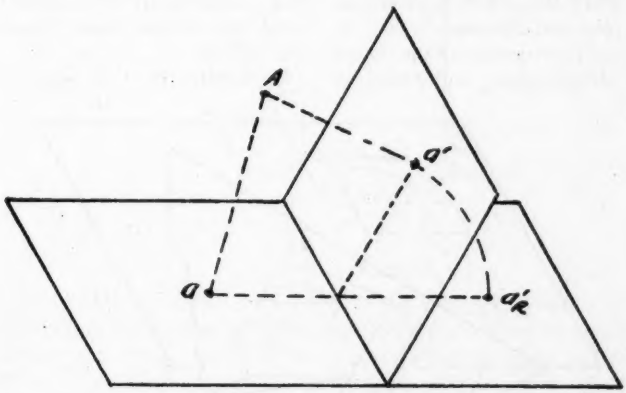


FIG. 3.

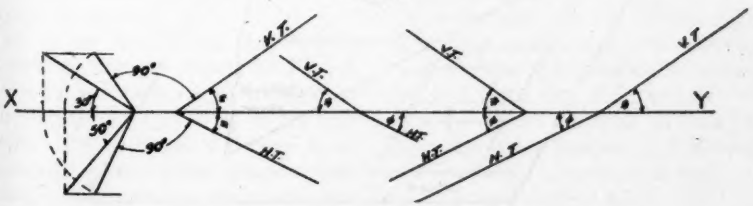


FIG. 4.

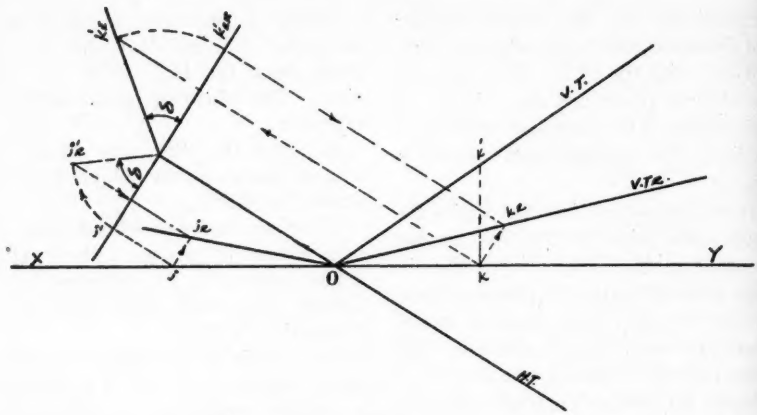


FIG. 5.

The steps in developing the method are now given:

1. Find the traces of an oblique plane such that when the object is placed as shown in plan and elevation in Fig. 6, an orthographic projection of the object upon the oblique plane will result in the correct foreshortening of the given axes.

2. Rotate the oblique plane, with the V.P. fixed rigidly to it, about the H.T. until the oblique plane coincides with the H.P.

3. Rotate the V.P. about the V.T.

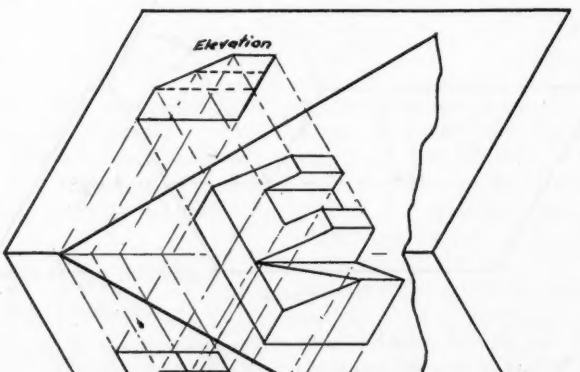


FIG. 6.

(in its new position) until it also coincides with the H.P.

The original trace of the H.P. upon the V.P. must be included in the rotation so that its final position may be determined, and the elevation of the object in its rabatted position will have the breadth axis parallel to this line.

4. Draw the plan and the elevation of the object in the rabatted positions and obtain the projection upon the oblique plane by projecting these views at right angles across the H.T. and V.T. respectively.

The application of these steps to the specific problem:

Set up the length axis OA and the depth axis OB as shown in Fig. 7. OA is to be foreshortened to $\frac{7}{8}$ of its true length and OB to $\frac{2}{3}$ of its true length. OA therefore will have to be projected upon some plane which makes with it an angle β whose cosine is $\frac{7}{8}$. One position of such a plane is shown by V.T.1 and H.T.1. If the plane be considered rigidly fixed to the line OA, and if it then be rotated about the line, its other positions may be visualized, *i.e.*, the line OD would describe the surface of a cone, and the plane in all its positions would be tangent to this cone. *In all its positions the plane would be inclined at an angle* $90° - \beta$ *to the vertical plane.*

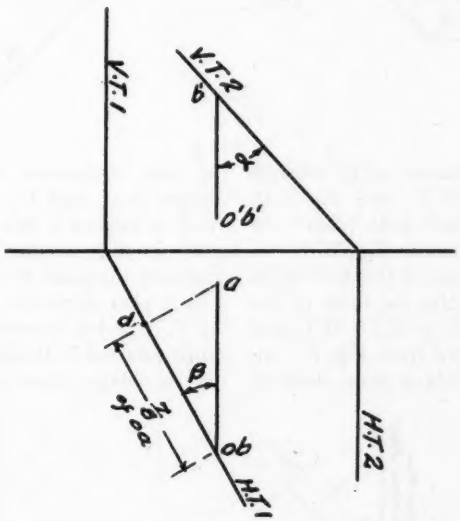


FIG. 7.

If the axis OB be now similarly considered, then it must be projected upon a plane which in all its positions makes an angle $90° - \alpha$ with the horizontal plane (where $\alpha = \cos^{-1} \frac{2}{3}$).

Combining both the above deductions, the object must be projected upon a plane which makes an angle of $90° - \beta$ with the V.P. and $90° - \alpha$ with the H.P. To draw its traces we must first draw the plan and elevation of a line which is inclined at angle α to the H.P. and angle β to the V.P. The resulting traces are shown in Fig. 8.

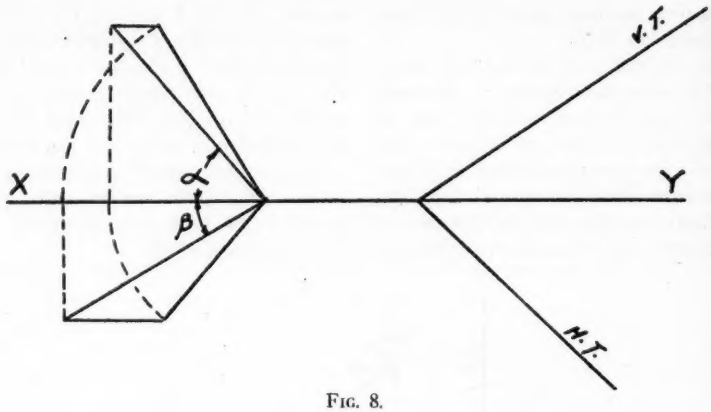


FIG. 8.

The two-fold rotation of the oblique plane about the H.T., and the V.P. about the V.T., until both planes are in the H.P., is shown in Fig. 9.

In Fig. 9 the trace of the V.P. upon the H.P. is XY, and the trace of the H.P. upon the V.P. is $X'Y'$; H.T. and V.T. are reproduced from Fig. 8. An edge view of the oblique plane, showing its true inclination to the H.P., is drawn next, and the point K on the V.T. is located in this view. The edge view is then rabatted into the H.P., carrying the point K with it. The line ok_R in plan shows the rabatted position of V.T. and is labelled $V.T_R$. At the same time the V.P. is held rigidly fixed to the oblique plane so that a point P

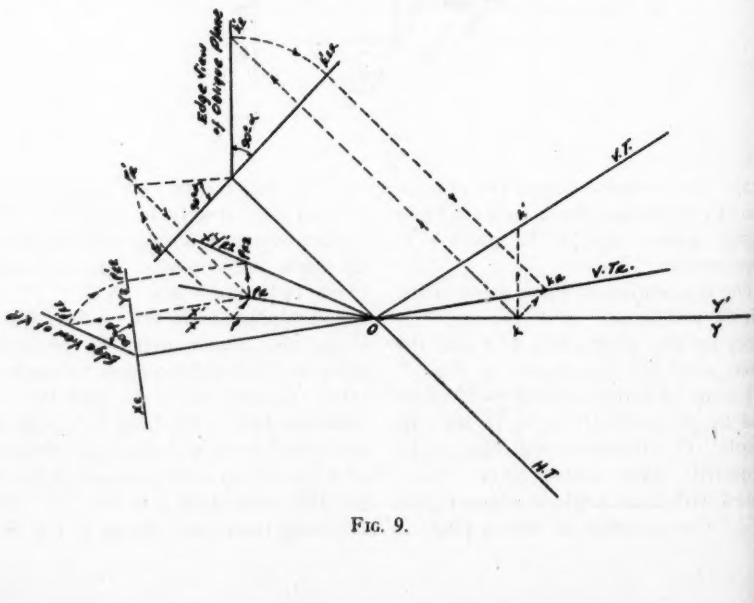


FIG. 9.

on $X'Y'$ is rotated through the same angle $90° - a$ as the edge view. This point maintains its relative position to the oblique plane, therefore the new position of OX will be shown by Op_R. Next, an edge view of the V.P. in its new position is constructed across X_2Y_2 which is perpendicular to $V.T_R$. This edge view will show the true angle $90° - \beta$ that the V.P. makes with the oblique plane. The point p'_R is located on the edge view, and the V.P. is then rabatted into the H.P., carrying P_R with it, so that the final position of $X'Y'$ will be shown by Op_{R2} and is labelled $X'Y'_{R2}$.

The plan and elevation of the object will now have the breadth axis parallel to XY and $X'Y'_{R2}$ respectively.

In Fig. 10 the lines XY, $X'Y'_{R2}$, $V.T_R$., and H.T. are reproduced from Fig. 9. The plan of the length axis is drawn perpendicular to the XY line, and the elevation of the height axis perpendicular to $X'Y'_{R2}$. The points from these two views are projected at right angles across the H.T. and $V.T_R$., and the true shape of the projection on the oblique plane results.

It should be noted particularly that the direction of the projecting lines from the plan is the same as the direction of the plan of the line first used to find the H.T.

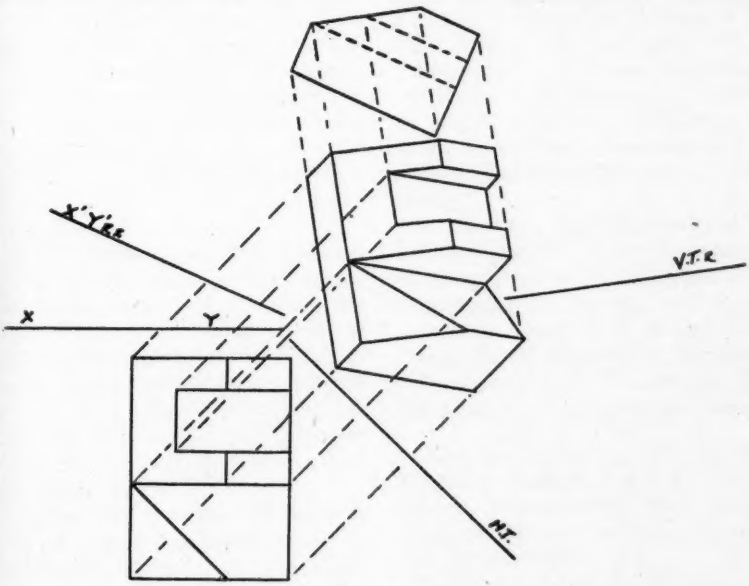


FIG. 10.

By checking the final projection it may be established that the foreshortening of the given axes is correct.

In consequence of these two facts, it is possible to obtain the required projection without the two-fold rotation, as explained in the construction of Fig. 2.

Had one of the other planes illustrated in Fig. 4 been chosen, the fore-

shortening of the axes would have been the same but the orientation of the object towards the observer would have been different. A little consideration of the problem will show that any orientation of the object towards the observer is possible with an appropriate choice of views of the object and the oblique plane upon which they are projected.

Had the foreshortening been stipulated for the length and breadth axes, those views of the object would have been chosen which permit the length axis to be perpendicular to the V.P. and breadth axis perpendicular to the H.P.; or the orientation of the axes could be left the same as in Fig. 1, if the profile plane were used to find the traces of the required plane. The adaptation of the method is left to the readers who are interested in drawing.

College Notes

The new officers (1947) of the **Middle Atlantic Section** are as follows: Chairman: Professor C. Higbie Young, The Cooper Union, New York City, N. Y.; Vice Chairman: Mr. Otto Carpenter, Western Electric Co., 195 Broadway, New York 7, N. Y.; Secretary-Treasurer: Professor William Allan, College of the City of New York, New York City, N. Y.

FRANK D. CARVIN,
Secretary.

The **University of Michigan** will conduct a Symposium on Fluid Mechanics during the Summer Session, June 23 to August 16. It will consist of course work conducted by Professor Hunter Rouse, Director of the Institute of Hydraulic Research of the State University of Iowa, and Professor Sydney Goldstein of the University of Manchester, England.

Lectures and seminars will be given by guest teachers including Boris A. Bakhmeteff, Professor of Civil Engineering, Columbia University; Dr. Hugh L. Dryden, Assistant Director National Bureau of Standards, Washington, D. C.; J. E. Warnock or D. J. Hebert of the Bureau of Reclamation; L. G. Straub, Professor of Civil Engineering and Director of the St. Anthony Falls Laboratory, University of Minnesota; John Stack, Chief of the Compressibility Division, NACA Laboratory, Langley Field; V. L. Streeter, Research Professor in Mechanics, Illinois Institute of Technology; M. J. Thompson, Professor and Chairman of Aeronautical Engineering, University of Texas; and Th. von Karman, Director Guggenheim Aeronautical Laboratory, California Institute of Technology.

Several men from the faculty of the University of Michigan will participate, including Prof. G. E. Uhlenbeck of the Department of Physics, and Professors L. A. Baier, E. F. Brater, R. A. Dodge. W. W. Hagerty, A. M. Kuethe, J. D. Schetzer, E. T. Vincent, and R. R. White, all of the College of Engineering.

The Fall Meeting of the **New England Section** A.S.E.E. will be held at Massachusetts State College, Amherst, Massachusetts, on Saturday, October 11, 1947.

Professor George A. Marston, Acting Head of the Division of Engineering at Massachusetts State College is acting as Chairman for the host institution.

W. E. KEITH,
Secretary.

Subject Index, 1946–47

ACCREDITING AGRICULTURAL ENGINEERING CURRICULA—VIEWPOINTS OF AGRICULTURAL ENGINEERING FACULTY MEMBERS. G. B. Nutt....5, 386
ADDRESS OF WELCOME. M. E. Deutsch.1, 70
ADMISSION TEST PROCEDURE. R. R. Slaymaker.....5, 402
AFTER VETERAN PROGRAMS, WHAT NEXT? H. L. Spencer.....10, 796
AGRICULTURE, MEETING THE ENGINEERING NEEDS OF. A. E. Turner....3, 525
AGRICULTURAL ENGINEERING CURRICULA—VIEWPOINTS OF AGRICULTURAL ENGINEERING FACULTY MEMBERS, ACCREDITED. G. B. Nutt.....5, 386
AGRICULTURAL ENGINEERING IN AGRICULTURE, PLACE OF. E. L. Anthony.....4, 310
AGRICULTURAL ENGINEERING TEACHERS HOLD SEMINAR.....3, 275
AGRICULTURAL ENGINEERING EDUCATION,. INDUSTRY REQUIREMENTS OF PROFESSIONAL. J. D. Long.....3, 210
AGRICULTURAL ENGINEERING TEACHERS HOLD SEMINAR.....3, 275
AIMS AND CONTENT OF UNDERGRADUATE COURSES IN MACHINE DESIGN. J. H. Billings.....7, 563
ALTERNATIVE METHODS OF VELOCITY DETERMINATION IN MECHANISMS. I. W. Smith.....7, 540
APTITUDE TESTS, PREDICTION OF AVERAGE CLASS ACHIEVEMENTS BY MEANS OF. W. C. Krathwohl.....3, 234
ARTS FOR ENGINEERS, THE FINE. H. L. Seaver.....10, 811
"A. S. 'DOUBLE' E."....7, 477
AUTHORS, WORLD-WIDE RESPONSIBILITIES OF TECHNICAL BOOK. J. S. Thompson.....5, 373
AWARDS: GEORGE WESTINGHOUSE AWARD. J. N. Goodier.....1, 5
GEORGE WESTINGHOUSE AWARD....3, 274
LAMME AWARD. Robert E. Doherty.1, 2
LAMME AWARD.....3, 273

BEAUTIFUL MINNESOTA AWAITS YOU..4, 283
BREAK-EVEN CHARTS, TEACHING THE. C. E. Bullinger.....3, 228

CALCULUS FOR ENGINEERING STUDENTS, MATHEMATICS BEYOND. F. H. Miller.....4, 330
CIVIL ENGINEERING CURRICULUM, HYDROGRAPHIC SURVEYING IN THE. M. O. Schmidt.....9, 727
"CLOSE-COUPLED" COOPERATIVE ENGINEERING EDUCATION. Albert Sobey.....7, 498
COLLEGE AND PROFESSIONAL REGISTRATION EXAMINATIONS. H. T. Person.....9, 714
COLLEGE SENIOR AND THE SMALL INDUSTRY. N. H. Memory.....2, 168
COMPARISON OF INDUSTRIAL ENGINEERING CURRICULA. J. M. Apple...10, 821
CONFERENCE ON EMERGENCY PROBLEMS IN HIGHER EDUCATION. W. E. Wickenden.....1, 77
COOPERATION BETWEEN DEPARTMENTS OF PHYSICS AND MECHANICS IN ENGINEERING COLLEGES. R. Z. Williams.....9, 720
COOPERATIVE ENGINEERING EDUCATION, "CLOSE-COUPLED." A. Albert Sobey.....7, 498
EFFECT OF THE WAR ON. L. F. Smith.....4, 340
SYSTEM—A MANIFESTO, REPORT OF COMMITTEE.....2, 117
COOPERATIVE SYSTEM—A MANIFESTO, REPORT OF COMMITTEE.....2, 117
COORDINATION OF TEACHING IN PHYSICS AND ENGINEERING MECHANICS. W. H. Michener.....8, 618
COORDINATED PROGRAM FOR PREPARATION OF ENGINEERING TECHNICIANS. E. E. Ericson.....2, 162
COORDINATION IN THE TEACHING OF MATHEMATICS TO ELECTRICAL ENGINEERS. L. V. Bewley.....10, 786
COUNCIL MEETINGS, MINUTES OF.....1, 16
COUNCIL, MEMBERS OF.....3, 199
COURSE REQUIREMENTS IN HUMANISTIC-SOCIAL STUDIES. M. V. McEnany.9, 704
CROFT, HUBER O., PRESIDENT.....1, 1

DEFINITION, PROFESSION OF ENGINEERING. A. G. L. Sullivan.....1, 64

DEMAND FOR AND SUPPLY OF ENGINEERING GRADUATES, OUTLOOK IN THE..1, 25
DIVERTING ATTENTION TO THE CLASSROOM. J. R. Killian, Jr.....3, 197
DRAWING DEPARTMENT, WHAT THE ELECTRICAL ENGINEERING DEPARTMENT NEEDS FROM THE. W. A. Lewis.....8, 653

ECONOMICS FOR ENGINEERS, PRACTICAL. C. E. Young.....4, 319
E.C.P.D. COMMITTEE FOR PROFESSIONAL RECOGNITION.....3, 268
EDUCATING INDUSTRIAL ENGINEERS FOR ACTION. G. B. Carson.....10, 843
EFFECT OF THE WAR ON COOPERATIVE EDUCATION. L. F. Smith.....4, 340
ELECTRICAL ENGINEERS, COORDINATION IN THE TEACHING OF MATHEMATICS TO. L. V. Bewley.....10, 786
ELECTRICAL ENGINEERING DEPARTMENT NEEDS FROM DRAWING DEPARTMENT, WHAT THE. W. A. Lewis.8, 653
EMPLOYMENT HISTORIES OF ENGINEERING GRADUATES. E. D. Howe...7, 513
ENGINEER AND HIS PLACE IN RESEARCH, THE. A. R. Cullimore.....10, 803
ENGINEERING EDUCATION IN THE FUTURE. A. D. Bailey.....7, 572
ENGINEERING EDUCATION, "PREVENTIVE MEDICINE" IN. G. W. Reid.....8, 638
ELECTRIC TRAINING FOR INDUSTRY. C. F. Dalziel, S. P. Wheeles, H. A. Moomaw.....7, 520
ENGINEERING COLLEGE RESEARCH COUNCIL, THE. F. M. Dawson.....10, 741
ENGINEERING COLLEGES AND THE U. S. OFFICE OF EDUCATION. H. H. Armsby.....8, 601
ENGINEERING EDUCATION IN LATIN AMERICA. S. S. Steinberg.....4, 297
ENGINEERING PROFESSOR IN A SOCIETY OF TRANSITION. A. H. Blaisdell.3, 222
ENGINEERS: WANTED. R. C. Price....1, 50
ENGINEER FAMILY IN THE BRITISH COMMONWEALTH. P. Dunsheath.....1, 96
ENGINEER'S FATHER, THE. T. J. MacKavanaugh.....1, 58
ENGLISH 113, AN EXPERIMENT IN READING. A. M. Buchan.....10, 780
ENROLLMENT OF ENGINEERING STUDENTS, 1946–47.....5, 463
ENROLLMENT IN MINERAL ENGINEERING SCHOOLS IN THE UNITED STATES AND CANADA AT AN ALL-TIME HIGH. W. B. Plank, F. W. Bloecher.....10, 765

EXAMINATION IN THE SELECTION OF GRADUATE ENGINEERING STUDENTS, USE OF THE GRADUATE RECORD. G. S. Speer.....4, 313

FILMS IN ENGINEERING EDUCATION, TYPES OF. M. C. Giannini.....5, 441
FINE ARTS FOR ENGINEERS, THE. H. L. Seaver.....10, 811
FIVE-YEAR CURRICULUM IN INDUSTRIAL ENGINEERING. P. N. Lehoczky..3, 246
FIVE-YEAR MECHANICAL ENGINEERING CURRICULUM. R. C. Jordan.....5, 414
FOOTNOTE AND FANCY FREE. J. A. Walter.....4, 356
FORGOTTEN MAN IN HIGHER EDUCATION, THE. A. A. Potter.....10, 777
FOUNDRY PRACTICE FOR ENGINEERING STUDENTS. H. F. Scobie.....9, 689

GENERAL ENGINEERING-SCIENCE. W. L. DeBaufre.....9, 696
GEORGE WESTINGHOUSE AWARD. J. N. Goodier.....1, 5; 3, 274
GRADUATE STUDY—THROUGH APPLIED MATHEMATICS, UNDERGRADUATE PREPARATION FOR. J. L. Synge..7, 531
GRAPHICAL AND ANALYTIC METHODS AS APPLIED TO AIRCRAFT DESIGN. S. A. Coons.....10, 858

HALF-EDUCATED ENGINEER, THE. B. M. Woods.....1, 60
HIDDEN HALF OF THE PROBLEM, THE. C. D. Crosno.....2, 149
HISTORY SOURCES, PRACTICAL GUIDES TO ENGINEERING. Harold Lancour...1, 68
HUMANISTIC-SOCIAL STUDIES, COURSE REQUIREMENTS IN. M. V. McEnany.....9, 704
IN ENGINEERING EDUCATION, PHILOSOPHY OF. E. S. Burdell.....8, 593
COURSES, PLANNING THE PROFESSIONAL ASPECT OF THE. B. R. Teare.....4, 344
IN ENGINEERING COLLEGES, SUMMARY OF INFORMATION CONCERNING THE. L. A. Rose.....4, 336
HUMANITIES, OPINION ON THE TRAINING OF TEACHERS IN THE. S. R. Price.1, 79
HYDROGRAPHIC SURVEYING IN THE CIVIL ENGINEERING CURRICULUM. M. O. Schmidt.....9, 727

INDUSTRIAL HYGIENE, SAFETY AND FIRE PREVENTION.....9, 673
INDUSTRIAL RELATIONS, WHAT THE ENGINEER SHOULD KNOW ABOUT. W. R. Spriegel.....Year book—1

INDUSTRY REQUIREMENTS OF PROFESSIONAL AGRICULTURAL ENGINEERING EDUCATION. J. D. Long....3, 210
INDUSTRY, OPPORTUNITIES FOR ENGINEERS IN. M. M. BORING....10, 759
INDUSTRY, ELECTRICAL TRAINING FOR. C. F. Dalziel, S. P. Welles, H. A. Moomaw....7, 520
SPECIAL ENGINEERING REQUIREMENTS OF THE SMALL. G. L. Hartman..2, 174
COLLEGE SENIOR AND THE SMALL. N. H. Memory....2, 168
INSTRUMENTATION. D. F. Miner....3, 216
INTERNATIONAL EDUCATIONAL RECONSTRUCTION, SUMMARY REPORT OF NATIONAL CONFERENCE ON. S. S. Steinberg....9, 730
INTERNATIONAL RELATIONS, TECHNOLOGY AND. N. J. Padelford....10, 751

JET PROPULSION—ITS EFFECT UPON ENGINEERING EDUCATION. F. J. Malina....2, 179

LAMME AWARD. Robert E. Doherty 1, 2; 3, 273
LATIN AMERICA, ENGINEERING EDUCATION IN. S. S. Steinberg....4, 297
LEARNING, SOME OBSERVATIONS ON. L. M. K. Boelter....5, 419
LETTER TO MR. DUERKSEN, AN OPEN. C. J. Freund....4, 281
LIGHTING DEVELOPMENTS AND THEIR APPLICATION TO DRAFTING ROOMS, NEW. R. C. Putnam....5, 389

MACHINE DESIGN, AIMS AND CONTENT OF UNDERGRADUATE COURSES IN. J. H. Billings....7, 563
MATHEMATICS TO ENGINEERS, TEACHING. L. E. Grinter....7, 536
TO ELECTRICAL ENGINEERS, COORDINATION IN THE TEACHING OF. L. V. Bewley....10, 786
UNDERGRADUATE PREPARATION FOR GRADUATE STUDY—THROUGH APPLIED. J. L. Synge....7, 531
AND RELATED FIELDS, QUALIFICATIONS FOR PROFESSIONAL POSITIONS IN APPLIED. R. S. Burington, D.C. May....8, 641
PREPARATION FOR ENGINEERING COLLEGES, REPORT ON. F. H. Miller, S. G. Roth....8, 628
IN CIVIL ENGINEERING. H. E. Wessman....5, 378
AND ELECTRICAL ENGINEERING. G. F. Corcoran....10, 818
BEYOND CALCULUS FOR ENGINEERING STUDENTS. F. H. Miller....4, 330
MECHANICS IN ENGINEERING COLLEGES, COOPERATION BETWEEN DEPARTMENTS OF PHYSICS AND. R. Z. Williams....9, 720
COORDINATION OF TEACHING IN PHYSICS AND ENGINEERING. W. H. Michener....8, 618
MECHANISMS, ALTERNATE METHODS OF VELOCITY DETERMINATION IN. I. W. Smith....7, 540
MEETING THE ENGINEERING NEEDS IN AGRICULTURE. A. W. Turner....3, 252
MEMBERS OF THE SOCIETY, TO THE. Huber O. Croft....1, 7
METHODS OF ACHIEVING PROFESSIONAL RECOGNITION. W. F. Ryan....5, 453
MINERAL ENGINEERING CURRICULA, POST-WAR. J. D. Forrester....3, 201
MINNESOTA AWAITS YOU, BEAUTIFUL. 4, 283
INSTITUTE OF TECHNOLOGY, THE UNIVERSITY OF....10, 743
VACATION LAND....8, 585
MINUTES OF COUNCIL MEETINGS....1, 16
OF 54TH ANNUAL MEETING....1, 19
OF EXECUTIVE BOARD....2, 107

NECROLOGY: Alexander R. Stevenson. 3, 269
Robert L. Sackett....3, 269
Clement C. Williams....7, 581
NEW ENGLAND SECTION, OPERATION OF THE....3, 243
NEW LIGHTING DEVELOPMENTS AND THEIR APPLICATION TO DRAFTING ROOMS. R. C. Putnam....5, 389
NEW MAGIC IN OLD LINES. Achille Presutti....7, 487
NEW METHOD OF AXOMETRIC PROJECTION, A. D. Maksymiuk....10, 871
NOTES ON THE PHILOSOPHY OF STRESS ANALYSIS. L. T. Wyly....8, 610

ON TEACHING QUALITY CONTROL. L. E. Simon....2, 111
OPEN LETTER TO MR. DUERKSEN, AN. C. J. Freund....4, 281
OPERATION OF THE NEW ENGLAND SECTION....3, 243
OPINION ON THE TRAINING OF TEACHERS IN THE HUMANITIES. S. R. Price..1, 79
OPPORTUNITIES FOR ENGINEERS IN INDUSTRY. M. M. Boring....10, 759
OUTLOOK IN THE DEMAND FOR AND THE SUPPLY OF ENGINEERING GRADUATES, REPORT OF COMMITTEE ON..1, 25

PHILOSOPHY OF HUMANISTIC-SOCIAL STUDIES IN ENGINEERING EDUCATION. E. S. Burdell....8, 593
PHYSICS AND MECHANICS IN ENGINEERING COLLEGES, COOPERATION BETWEEN DEPARTMENTS OF. R. Z. WILLIAMS....9, 720
AND ENGINEERING MECHANICS, COORDINATION OF TEACHING IN. W. H. Michener....8, 618
LABORATORY IN AN ENGINEERING SCHOOL. C. J. Pratt....10, 828
COLUMN....4, 371
PITY THE "IGNORANT" ENGINEER. D. J. Mack....10, 837
PLACE OF AGRICULTURAL ENGINEERING IN AGRICULTURE. E. L. Anthony.4, 310
PLANNING THE PROFESSIONAL ASPECT OF THE HUMANISTIC-SOCIAL COURSES. B. R. Teare....4, 344
POST-WAR MINERAL ENGINEERING CURRICULA. J. D. Forrester....3, 201
PRACTICAL ECONOMICS FOR ENGINEERS. C. E. Young....4, 319
PRACTICAL GUIDE TO ENGINEERING HISTORY SOURCES. Harold Lancour..1, 68
PRACTICAL TEACHING CREDO, A. A. D. Topping....10, 831
PREDICTIONS OF AVERAGE CLASS ACHIEVEMENTS BY MEANS OF APTITUDE TESTS. W. C. Krathwohl..3, 234
PRESIDENTIAL ADDRESS: THE THRESHOLD OF A NEW ERA. H. S. Rogers....1, 8
"PREVENTIVE MEDICINE" IN ENGINEERING EDUCATION. G. W. Reid....8, 638
PROBLEMS IN THE DEVELOPMENT OF TECHNICAL INSTITUTES IN CALIFORNIA. R. J. Smith....1, 72
PRODUCTION ILLUSTRATIONS. George Tharratt....2, 140
PROFESSION OF ENGINEERING—A DEFINITION. G. L. Sullivan....1, 64
PROFESSIONAL VICES OF TEACHERS OF SCIENCE AND ENGINEERING. B. B. Bennett....10, 825
PROJECTIONS OF A ROTATING VECTOR. L. E. Ritter....8, 616
PROOF OF THE KELVIN-HELMHOLTZ EQUATION FOR THE EQUILIBRIUM VAPOR PRESSURE ABOVE THE MENISCUS. W. O. Smith....10, 809

QUALIFICATIONS FOR PROFESSIONAL POSITIONS IN APPLIED MATHEMATICS AND RELATED SCIENTIFIC FIELDS. R. S. Burington, D. C. May....8, 641
QUALITY CONTROL, TEACHING OF STATISTICS FOR. L. A. Knowler....9, 709
ON TEACHING. L. E. Simon....2, 111
QUICK COURSES IN READING FOREIGN LANGUAGE FOR SCIENCE AND ENGINEERING GRADUATE STUDENTS. W. N. Locke....9, 732

RECOGNITION, METHODS OF ACHIEVING PROFESSIONAL. W. F. Ryan....5, 453
REEXAMINATION OF THE COMPTON REPORT. H. H. Armsby....9, 675
REGISTRATION EXAMINATIONS, COLLEGE AND PROFESSIONAL. H. T. Person....9, 714
REPORT ON MATHEMATICS PREPARATION FOR ENGINEERING COLLEGES. F. H. Miller, S. G. Roth....8, 628
REPORT TO THE MEMBERSHIP. E. B. Norris....2, 105
RESEARCH AND THE STAFF MEMBER. E. E. Litkenhous....2, 135

SECRETARY, REPORT OF THE. F. L. Bishop....2, 109
SECTIONS AND BRANCHES 2, 188; 4, 366; 8, 671
SEMINARS CAN BE FUN! J. S. Thompson....9, 736
SENIOR THESIS IN THE UNDERGRADUATE CURRICULUM. M. A. Hunter....7, 483
SIMPLE DEMONSTRATION OF THE CARRIER AND SIDE FREQUENCY COMPONENTS IN AN AMPLITUDE MODULATED WAVE. A. D. Bailey....5, 383
SOME ASPECTS OF ENGINEERING EDUCATION IN SOUTH AMERICAN, ESPECIALLY IN URUGUAY. S. Gerszonowicz....8, 660
SOME FUNDAMENTAL THEOREMS OF STRUCTURAL MECHANICS IN VECTOR NOTATION. R. J. Dunholter....3, 207
SOME MODIFICATIONS IN APPROACH TO TEACHING ENGINEERS. E. C. Shuman....5, 446
SOME OBSERVATIONS ON LEARNING. L. M. K. Boelter....5, 419
SPECIAL ENGINEERING REQUIREMENTS OF THE SMALL INDUSTRY. G. L. Hartman....2, 174
STATISTICS FOR QUALITY CONTROL, TEACHING OF. L. A. Knowler...9, 709
STRESS ANALYSIS, NOTES ON THE PHILOSOPHY OF. L. T. Wyly....8, 610
SUMMARY OF INFORMATION CONCERNING HUMANISTIC-SOCIAL COURSES IN ENGINEERING COLLEGES. L. A. Rose.4, 336
SUMMARY REPORT OF NATIONAL CONFERENCE ON INTERNATIONAL EDUCATION RECONSTRUCTION. S. S. Steinberg....9, 730

SUPPLY OF ENGINEERING GRADUATES, OUTLOOK IN THE DEMAND FOR AND. 1, 25

T-SQUARE PAGE. 3, 277; 7, 582
TEACHERS ARE HUMAN BEINGS. Charles E. Gus. 7, 558
TEACHING THE BREAK-EVEN CHART. C. E. Bullinger. 3, 228
TEACHING MATHEMATICS TO ENGINEERS. L. E. Grinter. 7, 536
TEACHING OF STATISTICS FOR QUALITY CONTROL. L. A. Knowler. 9, 709
TECHNICAL INSTITUTES IN CALIFORNIA, PROBLEMS IN DEVELOPMENT OF. R. J. Smith. 1, 72
TECHNICAL INSTITUTE SURVEY. 4, 353
TECHNOLOGICAL EDUCATION IN A DEMOCRACY. W. L. DeBaufre. 2, 153
TECHNOLOGY AND INTERNATIONAL RELATIONS. N. J. Padelford. 10, 751
THRESHOLD OF A NEW ERA, THE. H. S. Rogers. 1, 8
TREASURER, REPORT OF. J. S. Thompson. 1, 21
TRIVIA FROM OBLIVIA. E. C. Elliott. . 3, 260
TYPES OF FILMS IN ENGINEERING EDUCATION. M. C. Giannini. 5, 441

UNDERGRADUATE PREPARATION FOR GRADUATE STUDY—THROUGH APPLIED MATHEMATICS. J. L. Synge. 7, 531
UNESCO, A PROGRAM FOR PEACE THROUGH UNDERSTANDING. Huber O. Croft. 7, 478
U. S. OFFICE OF EDUCATION, ENGINEERING COLLEGES AND THE. H. H. Armsby. 8, 601

USE OF THE GRADUATE RECORD EXAMINATION IN THE SELECTION OF GRADUATE ENGINEERING STUDENTS. G. S. Speer. 4, 313

VALUATION OF PUBLIC UTILITIES: IS IT POSSIBLE TO RECONCILE ORIGINAL-COST AND REPRODUCTION-NEW THEORIES? A. S. Langsdorf. 4, 290
VECTOR, PROJECTION OF A ROTATING. L. E. Ritter. 8, 616
NOTATION, SOME FUNDAMENTAL THEOREMS OF STRUCTURAL MECHANICS IN. R. J. Dunholter. 3, 207
VETERANS TURNED SCHOLARS. C. J. Freund. 10, 762

WHAT THE ELECTRICAL ENGINEERING DEPARTMENT NEEDS FROM THE DRAWING DEPARTMENT. W. A. Lewis. 8, 653
WHAT THE ENGINEER SHOULD KNOW ABOUT INDUSTRIAL RELATIONS. W. R. Spriegel. . . . . Year book—1
WHERE ARE WE GOING? R. E. Doherty. 10, 771
WHY WE ENGAGE COLLEGE GRADUATES IN OUR ORGANIZATION. G. A. Waters. 3, 214
WILL COMPREHENSIVE COURSES MEET THE NEEDS OF ENGINEERS? A. L. Pugsley. 10, 840
WORLD-WIDE RESPONSIBILITIES OF TECHNICAL BOOK AUTHORS. J. S. Thompson. 5, 373

Author Index, 1946–47

ANTHONY, E. L., Place of Agricultural Engineering in Agriculture....4, 310
APPLE, J. M., Comparison of Industrial Engineering Curricula....10, 821
ARMSBY, H. H., Engineering Colleges and the U. S. Office of Education....8, 601
Reexamination of the Compton Report....9, 675

BAILEY, A. D., Simple Demonstration of the Carrier and Side Frequency Components in an Amplitude Modulated Wave....5, 383
Engineering Education in the Future....7, 572
BENNETT, B. B., Professional Vices of Teachers of Science and Engineering....10, 825
BEWLEY, L. V., Coordination in the Teaching of Mathematics to Electrical Engineers....10, 786
BILLINGS, J. H., Aims and Content of Undergraduate Courses in Machine Design....7, 563
BISHOP, F. L., Report of the Secretary.2, 109
BLAISDELL, A. H., The Engineering Profession in a Society Transition....3, 222
BLOECHER, F. W., AND W. B. PLANK, Enrollment in Mineral Engineering Schools in the United States and Canada at an All-Time High....10, 765
BOELTER, L. M. K., Some Observations on Learning....5, 419
BORING, M. M., Opportunities for Engineers in Industry....10, 759
BUCHAN, A. M., English 113, An Experiment in Reading....10, 780
BULLINGER, C. E., Teaching the Break-Even Chart....3, 228
BURDELL, E. S., Philosophy of Humanistic-Social Studies in Engineering Education....8, 593
BURINGTON, R. S., AND D. C. MAY, Qualifications for Professional Positions in Applied Mathematics and Related Fields....8, 641

CARSON, G. B., Educating Industrial Engineers for Action....10, 843
COONS, S. A., Graphical and Analytic Methods as Applied to Aircraft Design....10, 858
CORCORAN, G. F., Mathematics and Electrical Engineering....10, 818
CROFT, HUBER O., President....1, 1
UNESCO, a Program for Peace Through Understanding....7, 478
CROSNO, C. D., The Hidden Half of the Problem....2, 149
CULLIMORE, A. R., The Engineer and His Place in Research....10, 803

DALZIEL, C. F., S. P. WELLES, AND H. A. MOOMAW, Electric Training for Industry....7, 520
DAWSON, F. M., The Engineering College Research Council....10, 741
DEBAUFRE, W. L., General Engineering-Science....9, 696
DEUTSCH, M. E., Address....1, 70
DOHERTY, R. E., Where Are We Going?....10, 771
DUNHOLTER, R. J., Some Fundamental Theorems of Structural Mechanics in Vector Notations....3, 207
DUNSHEATH, P., Engineering Family in the British Commonwealth....1, 96

ELLIOTT, E. C., Trivia from Oblivia...3, 260
ERICSON, E. E., Coordinated Program for Preparation of Engineering Technicians....2, 162

FORRESTER, J. D., Post-War Mineral Engineering Curricula....3, 201
FREUND, C. J., An Open Letter to Mr. Duerksen....4, 281
Veterans Turned Scholars....10, 762

GERSZONOWICZ, S., Some Aspects of Engineering Education in South America, Especially in Uruguay....8, 660
GIANNINI, M. C., Types of Films in Engineering Education....5, 441
GRINTER, L. E., Teaching Mathematics to Engineers....7, 536
GUS, CHARLES E., Teachers Are Human Beings....7, 558

HARTMAN, G. L., Special Engineering Requirements of the Small Industry....2, 174
HOWE, E. D., Employment Histories of Engineering Graduates....7, 513

HUNTER, M. A., Senior Thesis in the Undergraduate Curriculum.....7, 483

JORDAN, R. C., Five-Year Mechanical Engineering Curriculum.....5, 414

KILLIAN, J. R., JR., Diverting Attention to the Classroom.....3, 197
KNOWLER, L. A., Teaching of Statistics for Quality Control.....9, 709
KRATHWOHL, W. C., Prediction of Average Class Achievements by Means of Aptitude Tests.....3, 235

LANCOUR, HAROLD, Practical Guides to Engineering History Sources.....1, 68
LANGSDORF, A. S., Valuation of Public Utilities: Is It Possible to Reconcile Original-Cost and Reproduction-New Theories.....4, 290
LEHOCZKY, P. N., Five-Year Curriculum in Industrial Engineering.....3, 246
LEWIS, W. A., What the Electrical Engineering Department Needs from the Drawing Department.....8, 653
LITKENHOUS, E. E., Research and the Staff Member.....2, 135
LOCKE, W. N., Quick Courses in Foreign Language for Science and Engineering Graduate Students.....9, 732
LONG, J. D., Industry Requirements of Professional Agricultural Engineering Education.....3, 210

MACK, D. J., Pity the "Ignorant" Engineer.....10, 837
MACKAVANAUGH, T. J., The Engineer's Father.....1, 58
MAKSYMIUK, D., A New Method of Axometric Projection.....10, 871
MALINA, F. J., Jet Propulsion—Its Effect Upon Engineering Education.....2, 179
MAY, D. C., R. S. BURINGTON, Qualifications for Professional Positions in Applied Mathematics and Related Fields.....8, 641
MCENANY, M. V., Course Requirements in Humanistic-Social Studies.....9, 704
MEMORY, N. H., College Seniors and the Small Industry.....2, 168
MICHENER, W. H., Coordination of Teaching in Physics and Engineering Mechanics.....8, 618
MILLER, F. H., Mathematics Beyond Calculus for Engineering Students.4, 330
MILLER, F. H., AND S. G. ROTH, Report on Mathematics Preparation for Engineering Colleges.....8, 628
MINER, D. F., Instrumentation.....3, 216
MOOMAW, H. A., S. P. WELLES, AND C. F. DALZIEL, Electric Training for Industry.....7, 520

NORRIS, E. B., A Report to the Membership.....2, 105
NUTT, G. B., Accrediting Agricultural Engineering Curricula—Viewpoints of Agricultural Engineering Faculty Members.....5, 386

PADELFORD, N. J., Technology and International Relations.....10, 751
PERSON, H. T., College and Professional Registration Examinations.....9, 714
PLANK, W. B., AND F. W. BLOECHER, Enrollment in Mineral Engineering Schools in the United States and Canada at an All-Time High....10, 765
POTTER, A. A. The Forgotten Man in Higher Education.....10, 777
PRATT, C. J., Physics Laboratory in an Engineering School.....10, 828
PRESUTTI, ACHILLE, New Magic in Old Lines.....7, 487
PRICE, R. C., Engineers: Wanted.....1, 50
PRICE, S. R , Opinions on the Training of Teachers in the Humanities.....1, 79
PUGSLEY, A. L., Will Comprehensive Courses Meet the Needs of Engineers?.....10, 840
PUTNAM, R. C., New Lighting Developments and Their Applications to Drafting Rooms.....5, 389

REID, G. W., "Preventive Medicine" in Engineering Education.....8, 638
RITTER, L. E., Projections of a Rotating Vector.....8, 616
ROGERS, H. S., Presidential Address: The Threshold of a New Era.....1, 8
ROSE, L. A., Summary of Information Concerning the Humanistic-Social Studies in Engineering Colleges...4, 336
ROTH, S. G., AND F. H. MILLER, Report on Mathematics Preparation for Engineering Colleges.....8, 628
RYAN, W. F., Methods of Achieving Professional Recognition.....5, 453

SCHMIDT, M. O., Hydrographic Surveying in the Civil Engineering Curriculum.....9, 727
SCOBIE, H. F., Foundry Practice for Engineering Students.....9, 689
SEAVER, H. L., The Fine Arts for Engineers.....10, 811

SHUMAN, E. C., Some Modifications in Approach to Teaching Engineers. 5, 446
SIMON, L. E., On Teaching Quality Control. 2, 111
SLAYMAKER, R. R., Admission Test Procedure. 5, 402
SMITH, I. W., Alternative Methods of Velocity Determination in Mechanisms. 7, 540
SMITH, L. F., Effect of the War on Cooperative Engineering Education. 4, 340
SMITH, R. J., Problems in the Development of Technical Institutes in California. 1, 72
SMITH, W. O., Proof of the Kelvin-Helmholtz Equation for the Equilibrium Vapor Pressure Above a Meniscus. 10, 809
SOBEY, ALBERT, "Close-Coupled" Cooperative Engineering Education. 7, 498
SPEER, G. S., Use of the Graduate Record Examination in the Selection of Graduate Engineering Students. 4, 313
SPENCER, H. L., After Veteran Programs, What Next? 10, 796
SPRIEGEL, W. R., What the Engineer Should Know About Industrial Relations. Year book—1
STEINBERG, S. S., Engineering Education in Latin America. 4, 297
Report of Conference on International Educational Reconstruction. 9, 730
SULLIVAN, G. L., Profession of Engineering—A Definition. 1, 64
SYNGE, J. L., Undergraduate Preparation for Graduate Study—Through Applied Mathematics. 7, 531

TEARE, B. R., Planning the Professional Aspects of the Humanistic-Social Course. 4, 344
THARRATT, GEORGE, Production Illustration. 2, 140
THOMPSON, J. S., Report of the Treasurer. 1, 21
World-Wide Responsibilities of Technical Books. Authors. 5, 373
THOMPSON, J. T., Seminars Can Be Fun! 9, 736
TOPPING, A. D., A Practical Teaching Credo. 10, 831
TURNER, A. W., Meeting the Engineering Needs of Agriculture. 3, 252

WALTER, J. A., Footnote and Fancy Free. 4, 356
WATERS, G. A., Why We Engage College Graduates in Our Organization. 3, 214
WELLES, S. P., C. F. DALZIEL, AND H. A. MOOMAW, Electric Training for Industry. 7, 520
WESSMAN, H. E., Mathematics in Civil Engineering. 5, 378
WICKENDEN, W. E., Conference on Emergency Problems in High Education. 1, 77
WILLIAMS, R. Z., Cooperation Between Departments of Physics and Mechanics in Engineering Colleges. 9, 720
WOODS, B. M., The Half-Educated Engineer. 1, 60
WYLY, L. T., Notes on the Philosophy of Stress Analysis. 8, 610

YOUNG, C. E., Practical Economics for Engineers. 4, 319